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EPOCA-95 Cruise Report

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The EPOCA 95 expedition (Environmental Pollution and Oceanography in Arctic Seas) departed Hammerfest, Norway on the Norwegian Defense Research Establishment (NDRE) ship H.U. Sverdrup II on 25 August 1995 and returned to the same port on 25 September 1995. This cruise was planned to collect data and samples in the Kara Sea in order to assess the impact of anthropogenic pollution both radioactive and chemical on one of the marginal Arctic seas and to study the oceanography of the Kara Sea in order to better understand circulation and transport pathways of potential pollutants. This expedition included measurements near dump sites for the fueled reactors dumped by the former Soviet Union. The expedition traveled over 3200 nautical miles within the operating area acquiring Acoustic Doppler Current Profiles (ADCP), parametric sonar and bathymetry data. Current meter moorings were deployed at 17 stations. CTD stations with fluorometry and light transmission measurements were made at 118 sites. Water samples were obtained from 40 stations, sediment samples from 26 stations, large volume water samples and box cores were obtained at 19 stations. The cruise exceeded most of the operating plan expectations.

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Executive Summary

The EPOCA 95 expedition (Environmental Pollution and Oceanography in Arctic Seas) departed Hammerfest, Norway on the Norwegian Defense Research Establishment (NDRE) ship H.U. Sverdrup II on 25 August 1995 and returned to the same port on 25 September 1995. This cruise was planned to collect data and samples in the Kara Sea in order to assess the impact of anthropogenic pollution both radioactive and chemical on one of the marginal Arctic seas and to study the oceanography of the Kara Sea in order to better understand circulation and transport pathways of potential pollutants. This expedition included measurements near dump sites for the fueled reactors dumped by the former Soviet Union.

The expedition traveled over 3200 nautical miles within the operating area acquiring Acoustic Doppler Current Profiles (ADCP), parametric sonar and bathymetry data. Current meter moorings were deployed at 17 stations. One Aanderaa current meter was recovered after a year long deployment in the western Kara Sea. Three new current rigs were deployed for another one year deployment. CTD stations with fluorometry and light transmission measurements were made at 118 sites.

Water samples were obtained from 40 stations, sediment samples from 26 stations, large volume water samples and box cores were obtained at 19 stations and *in situ* gamma ray background spectra were obtained from two stations. Samples were acquired in the vicinity of a barge first located in 1993 by the Geolog Fersman as well as near the sites of the dumped reactors in the eastern Novoya Zemlya trough, Abrosimov Bay, Stepovoy Bay, Tsivolka Bay and Techeniya Bay. Many of the stations were in the Ob and Yenisey river dominated regions including the frontal region between the eastern and western Kara Sea. In addition, several stations were taken east of the Yenisey and one station in the northeast quadrant of the Kara. The cruise exceeded most of the operating plan expectations.

The preliminary conclusions are as follows:

1. The radioactivity in the water column is consistent with other reported values and is generally low compared with other seas. We successfully collected samples for gamma-ray spectrometry (^{137}Cs and others), ^{90}Sr, Pu, ^{129}I, ^{210}Pb.

2. No "hot spots" have been found. In the on-board gamma ray spectrometry the only anthropogenic isotope observed was ^{137}Cs.

3. An experiment to measure the distribution coefficient K_d was highly successful and should yield much needed data for the transport of radionuclides.

4. In contrast to published atlases, the surface circulation observed in the western Kara Sea was principally northward and not a counterclockwise gyre.

EPOCA-95 CRUISE REPORT

1.0 INTRODUCTION

1.1 Goals

The goals of the U.S. participation in the Environmental Pollution and Oceanography in Arctic Seas (EPOCA 95) expedition are four fold. First, to study oceanography of the central Kara Sea with particular emphasis on studying the frontal region at the edge of the Yamal plateau and the benthic boundary flow. Second, to establish the K_d partition coefficients as a function of location and water mass by a unique at-sea protocol. Third, to map the distribution of radionuclides in both the sediment and water column in the Kara Sea, to monitor sites measured in prior expeditions, and to collect data for the deployment of long term monitoring stations. Finally, to increase international cooperation in these areas of Arctic research. The U.S. contribution to this program was funded under the ONR Arctic Nuclear Waste Assessment Program (ANWAP).

1.2 General Description of Expedition

The expedition departed Hammerfest, Norway on the Norwegian Defense Research Establishment oceanographic ship H.U. Sverdrup II. The ship is 55 m long, with a 13 m Beam and draws 5.43 m. The ship is equipped with both a 5 and 10 ton A frame. A schematic of the ship is given in figure 1.1. The ship has a crew of 7 including the captain, first officer, chief engineer, two Able Bodied Seamen, steward and steward's assistant. The technical staff consisted of 6 scientist and engineers from NDRE, a Norwegian military officer working on a masters degree in Nautical Science, a physical oceanographer, physicist and a sea technician from the U.S. Naval Research Laboratory and a chemical oceanographer from the International Atomic Energy Agency - Marine Environment Laboratory (IAEA-MEL). The cruise was planned for 30 days with 22 days in the Kara Sea. The direct ship support costs were shared by NRL and NDRE.

The expedition received technical support by the U.S. Naval Ice Center with twice weekly ice charts as well as forecasting services. This year the ice was at an extreme minimum and was not a significant concern. A typical ice chart received via INMARSAT is shown in figure 1.2. Weather forecasting in the Kara Sea was provided by the U.S. Naval Atlantic Meteorological and Oceanographic Center.

1.3 Acknowledgments

We would like to acknowledge the dedicated efforts of our Norwegian colleagues in this research especially Øivind Grenness, the chief Norwegian scientist for EPOCA. Thanks also to Mr. Steve Sova, our sea technician, for his many contributions in support of our research. Finally, we wish to thank Captain Jan Loennechen and the Sverdrup II crew for getting us to the Kara Sea and returning safely, for outstanding assistance in our endeavors and for taking care of us so well during the expedition.

Manuscript approved December 22, 1995.

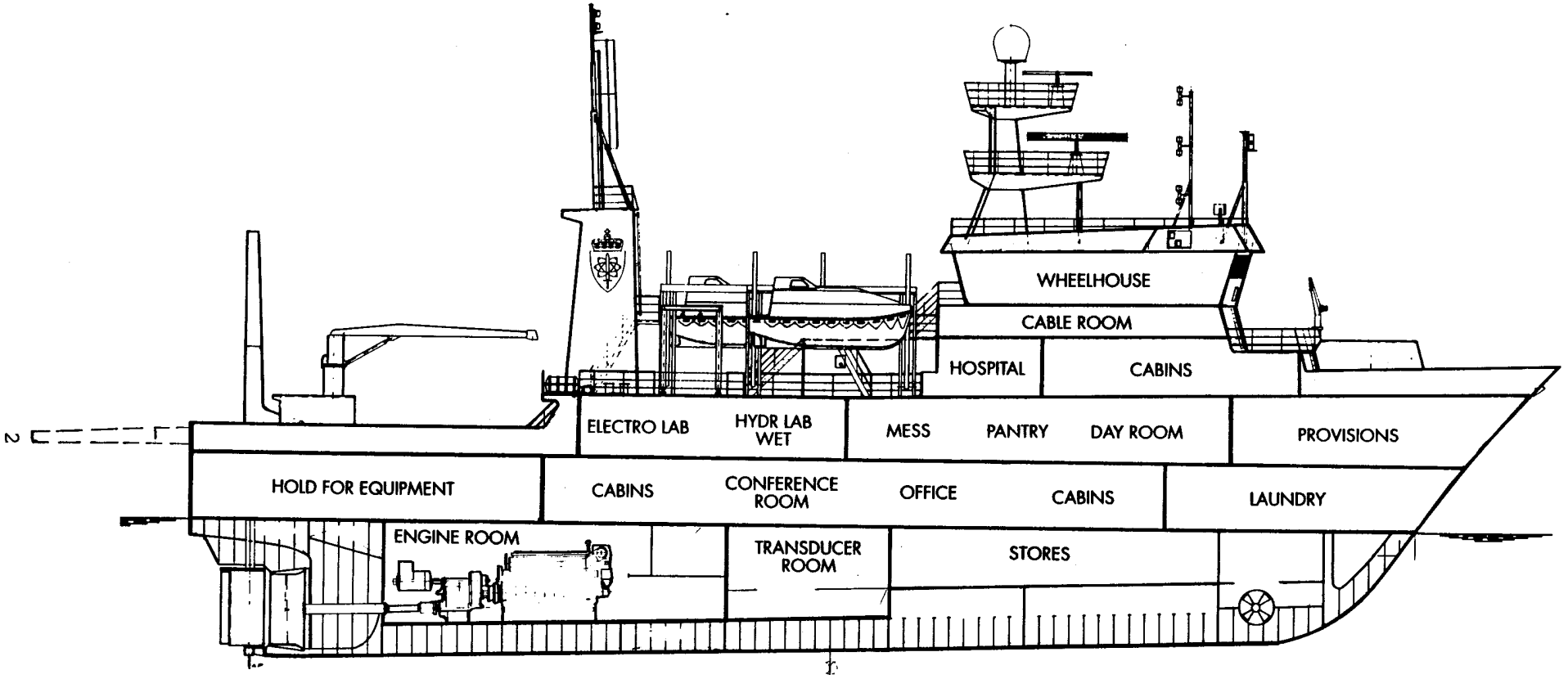

Figure 1.1 Schematic of H.U. Sverdrup II

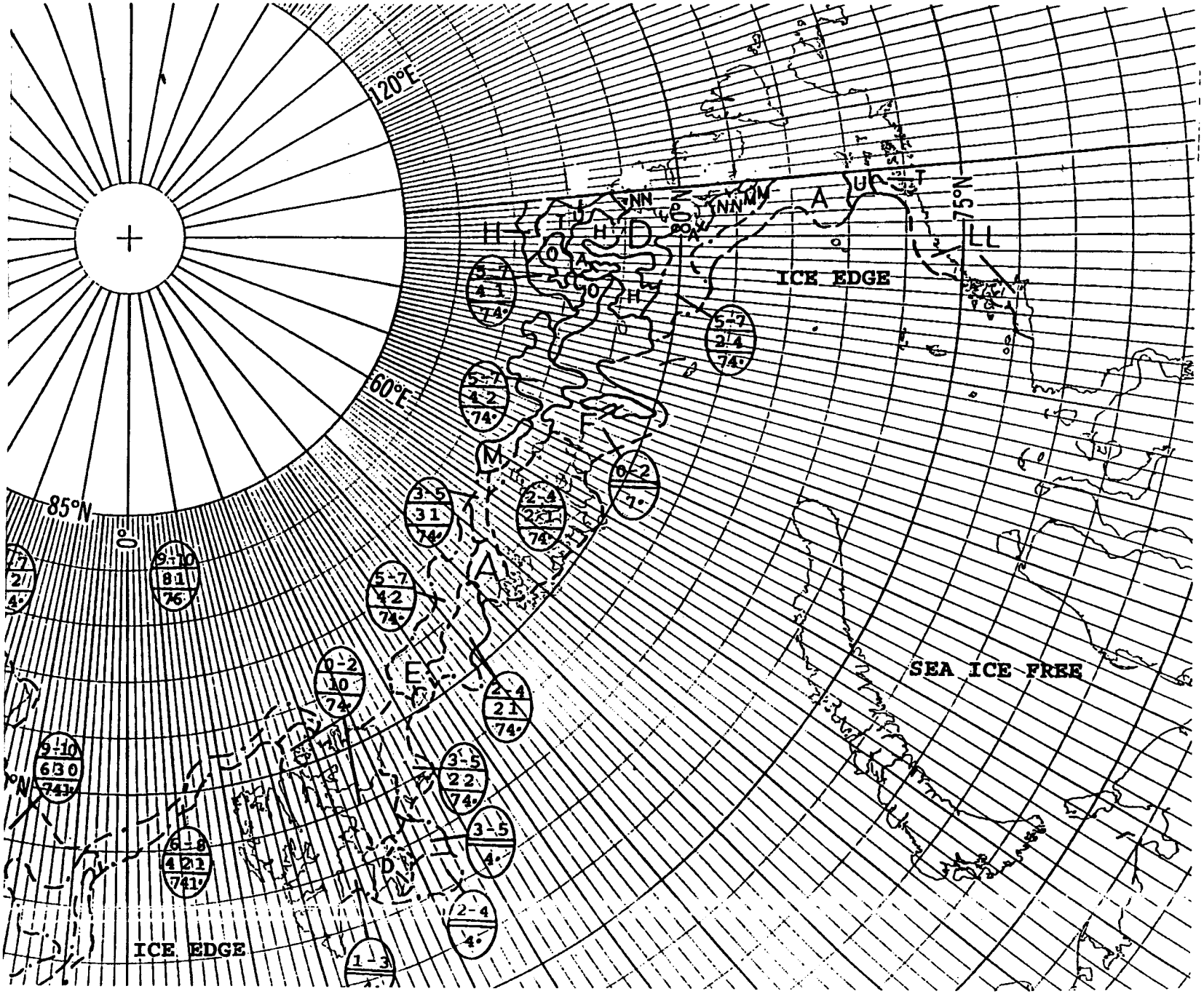

Figure 1.2 Ice Chart of Kara Sea and Vicinity for 16 August 1995

2.0 NARRATIVE LOG

The Kara Sea shown in figure 2.1 is a relatively shallow, river-dominated Arctic adjacent sea whose main topographic features consist of the Ob-Yenisey Delta (characteristically 25 m deep) and the East Novaya Zemlya Trough (over 300 m deep in spots). Figure 3.2 shows the observational track of the ADCP and serves as the ship-track chart. A detailed description of the ship movements, stations and work at each station is given in the condensed log (table 2.1).

The expedition departed Hammerfest, Norway on 25 August 1995 and entered the Kara sea on 28 August 1995. Entering around the north tip of Novaya Zemlya, we sampled on a direct line toward Dikson. This line coincided with a line established in previous cruises and provided a means for estimating interannual changes. Besides investigating the river entrances, figure 3.2 shows a concentration of effort along the delta edge and an incursion into the southern area with a section across the Kara Gate. Further effort was expended around the dump sites in the East Novaya Zemlya Trough. The barge first located by the Geolog Fersman in 1993 was relocated at essentially the same coordinates. Samples were acquired in close vicinity of the sunken barge. Prelimiary measurements were made using an underwater NaI detector was placed on the sea floor to obtain background data for a related ANWAP radiation monitoring project. The ship departed the Kara Sea on 21 September and returned to Hammerfest on 24 September 1995, 12 hours ahead of schedule. During EPOCA-95, 6120 km of underway measurements (current and temperature/salinity) were made together with 118 hydrographic stations and 40 water sampling stations and 26 sediment sampling stations. In addition, 17 current moorings were deployed.

Table 2.1 Condensed Chronological Log of Stations and Activities. The latitude and logitude are given in degree/minutes format N and E respectively, the depth is in meters, the date time group is in the format: ddhhmm in zulu time, the CTD column indicates when CTDs were taken and if bottles (BTL) of water were acquired, the sediment was collected by grab sampler (GRB) or box corer (BOX), the large volume water samples were taken at bottom (B) and surface (S) depths and the depths of the current rig deployment are indicated under Current Rig. The designation Radam indicates deployment of the underwater NaI gamma-ray detector.

Station	Latitude	Longitude	Depth	Arrival DTG(Z)	CTD	Sediment	Water	Current Rig
Departure Hammerfest:				251600 for 830 miles transit to pos 501				
501	7717.5	06807	408	281520	BTL	GRB	B+S	
502	7618.5	06940	130	290710	BTL	GRB		±10
503	7634.5	07148	180	291300	x			±10
504	7607	07227	115	291800	x			
505	7549.8	07323	107	292045	BTL	GRB		±3
506	7536.5	07403	54	292355	x			±3
507	7518	07500	49	300428	x			
508	7503.4	07545	39	300650	x			±3
509	7450	07623	37	301020	BTL	GRB		
510	7435	07710	35	301250	x			
511	7419.6	07755	30	301500	x			
512	7403.5	07843	28	301808	x			
513	7345	07827.5	24	302030	BTL	GRB		
514	7347	07900	29	310110	x			
515	7348	07940.5	33	310250	x	GRB		
516	7418	08106	40	310715	x			
518	7500	08342	49	311358	x			
519	7534.4	08557.6	54	311453	BTL		B+S	
520	7350	07605	23	020605	BTL			
521	7322.5	07300	30	021305	BTL	BOX	B+S	
522	7325	07233	25	021645	x			
523	7356	07343	25	022040	BTL		B+S	10,±3
524	7410	07321	31	022345	x			
525	7424	07300	29	030030	x			(1,2,3,13,-3)
526	7438	07236	29	030458	BTL	GRB		
527	7452.5	07210	34	030825	x	failed cur. rig depl. Recovered		
528	7505	07150	31	031310	x			
529	7515.9	07133	30	031516	x			
530	7517.5	07130	39	031543	x			
531	7519	07127	64	031608	x			
532	7520.5	07125	128	031629	x			
533	7522.2	07122	161	031702	x			
531	7519	07127	120	031818				30,±3
534	7530	07108	251	032210	BTL			
535	7526	06909	135	040235	x			
536	7506	06932	56	040508	x			
5271	7452.5	07210	32	041010	BTL			13, ±3
5370	7443	06959	26	041441	x			
5380	7443	06902	39	041620	x			
5381	7443	06855	44	041643	x			
5382	7443	06847	59	041710	x			

Table 2.1 continued

Station	Latitude	Longitude	Depth	Arrival DTG(Z)	CTD	Sediment	Water	CUR RIG
5383	7443	06840	77	041736	x			
5384	7443	06832	104	041813	x			
5381	7443	06854.5	46	041925				±3
5390	7443	06733	121	042245	x			
5400	7426	06743	173	050050	x			
5401	7424	06750.5	120	050125	x			
5402	7422	06758	51	050150	x			
5403	7420	06800	53	050217	x			
5404	7412	06810	48	050317	x			
5405	7355	06915	15	050624	x			
5410	7355	06830	28	050831	BTL	BOX	B+S	
5420	7355	06747	38	051215	x			
5421	7355	06739	37	051239	x			
5422	7355	06731	50	051300	x			
5423	7355	06723	140	051325	x			
5424	7355	06715	136	051353	x			
5430	7355	06636	55	051516	x			
5431	7355.2	06627	109	051628	BTL	BOX	B+S	3, 80, -6
5425	7355	06700	71	052225	x			3, 50, -6
5422	7355	06731	51	060110				3, 30, -6
5431	7355.3	06626	100	0600440	pulled cur. rig toward shallower water			
5440	7355	06533	162	060615	x			
5450	7321	06458	114	061015	x			
5460	7249	06425	60	061418	BTL	GRB		10, 25
5470	7211	06608	151	062307	x			
5480	7212	06443	110	070205	x			
5490	7213	06320	104	070454	x			
5500	7140	06214	114	070853	x			
5510	7107	06107	106	071306	BTL			
5520	7030.5	06000	160	071732	x			
5530	7038.2	05942	183	071840	x			
5540	7042.6	05918	204	072004	BTL	BOX	B+S	
5550	7047.4	05854	207	080355	x			
5560	7052.4	05830	224	080624	x			
5570	7056.9	05807	229	080830	BTL		B+S	
5580	7105	05755	248	081546	x			
5590	7129	05729	292	081912	x			
5600	7155	05625	299	090600	BTL	BOX	B+S	
5610	7227	05638	324	091255	BTL	BOX	B+S	Radam
5620	7218.1	05738.1	350	101520	BTL	BOX		
5630	7218.4	05738.4	354	101633		BOX	B+S	
5640	7117.9	05738.35	350	102040	BTL	BOX	B	
5650	7216	05903	98	110247	x			
5660	7215	06028	113	110532	x			
5670	7214	06153	124	110815	x			
5680	7240	05812	375	111850	BTL	BOX	B+S	
5690	7306	05842	389	120140	x			
5700	7330	05912	381	120410	x			
5710	7353	05940	310	120647				recovery

Table 2.1 continued

Station	Latitude	Longitude	Depth	Arrival DTG(Z)	CTD	Sediment	Water	CUR RIG
5720	7408	05951	285	121225	BTL	BOX	B+S	
5712	7353	05941	345	121815	BTL			10
5721	7405.6	06033	384	122210	BTL			
5722	7401.6	06309	140	130258	x			
5723	7358.3	06448	236	130608	x			
5724	7355	06621	98	131312	BTL		B	
5431	7355	06627	100	131550				recover 3
5425	7355	06700	70	131838				recover 3
5422	7355	06731	50	132145				recover 3
5381	7443	06854.5	46	130614	BTL			recover 2
5050	7549	07323	116	141640				recover R2
5060	7536.5	07403	53	141855				recover 2
5080	7503.5	07545	41	150005	BTL			recover 2
5081	7505.3	07710	47	150418	x			
5082	7507.2	07835	34	141900	x			
5083	7509	08000	45	142130	BTL			
5084	7444	08135	38	150100	x			
5160	7418	08106	40	152240	BTL			
5150	7348	07941	33	160558	BTL	BOX	B+S	
5140	7347	07900	28	161000	BTL	BOX		
5130	7345	07827	24	161400	BTL	BOX		Radam
5231	7340	07320	29	171320	BTL	BOX	B+S	
5230	7356	07343	25	171800	BTL	BOX	B+S	recover 3
5250	7424	07300	29	180454	x			recover 5
5271	7452.5	07210	33	180915	BTL		B+S	recover 3
5310	7519	07127	50	181413	x			recover 3
5311	7525.6	07022	197	181620	x			
5312	7532	06915	217	181840	x			
5313	7538.5	06807	335	182100	BTL			
5760	7546	06658	280	182330	BTL	BOX	B+S	10
5020	7618.6	06941	134	190915				recover 2R
5021	7626.5	07044	204	191701	x			
5030	7634.5	07148	180	191900				recover 2R
5031	7702.2	07554	140	200030	x			
5001	7830	08000	60	200606	BTL	BOX	B+S	
5002	7730	07540	252	201335	x			
5003	7730	07120	242	201845	x			
5004	7730	07015	312	202020	x			
5005	7730	06915	420	202215	x			
5006	7730	06823	511	210120	x			
5009	7730	06730	404	210300	x			
5011	7815	06400	388	211300	Current rig recovery attempts			
5011	7815	06400	388	212115	Depart from pos. 5011			
Arrival Hammerfest:				241800	after 810 mile return transit			

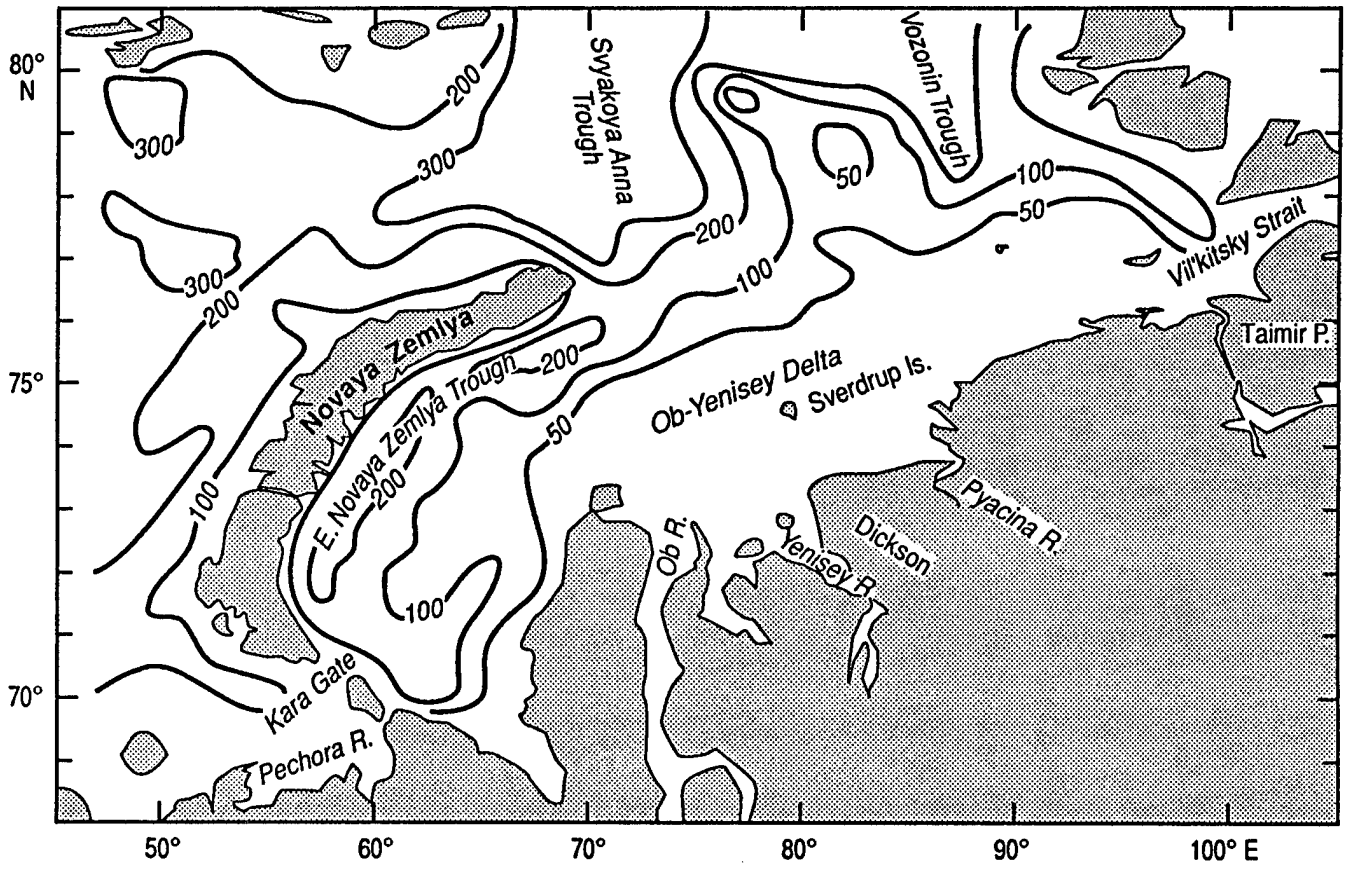

Figure 2.1 Kara Sea bathymetry. Depth is given in meters.

3.0 MEASUREMENTS AND SAMPLE COLLECTION

3.1 Oceanography

3.1.1 Current Meter Moorings

A total of 17 current rigs were deployed during the cruise. Fourteen were of limited duration (2-3 weeks) and were retrieved toward the end of the cruise. Three moorings were left for study of longer term changes overwinter. One additional current rig was retrieved after overwintering from the 1994 summer cruise. All instruments were Aanderaa current meters. Most of the instruments had conductivity and temperature sensors and wave responsive rotors. In deeper water (i.e., off the Ob/Yenisey delta), instruments were generally rigged at a depth of 10 m below the surface and 10 m above the bottom. Seven moorings had intermediate level instruments and one of these moorings had instruments at 1 m, 2 m and 3 m above the bottom.

Figure 3.1 shows the location of the 14 short term moorings. One of our objectives was to test the hypothesis that the delta edge provided a soft barrier for transport of river water toward the northwest due to the presence of an along slope current jet, found during the 1994 cruise. Other placements were designed to test for the presence of the inflow/outflow around the north tip of Novaya Zemlya and to determine bottom stress and the potential for resuspension of sediments.

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3.1.2 ADCP

The Acoustic Doppler Current Profiler (ADCP) measures currents below the ship's hull to a depth of 100-200 m with vertical resolution of 2-8 m. Due to hull interference, however, observations closer than 14 m from the surface were eliminated as spurious. Figure 3.2 shows the location of along-track measurements by the ADCP. A total of 6120 km of ADCP tracks were obtained during the cruise. This was a major achievement and provided an excellent overview of currents, especially in the southwestern Kara Sea where few measurements have previously been reported.

3.1.3 CTD with Rosette Water Sampler

The CTD sampling sensor suite is comprised of a Seabird CTD (Conductivity, Temperature, Depth sensors), a Seabird underwater pump, a SeaTech fluorometer (measuring stimulated chlorophyll-a, an indication of phytoplankton biomass), and a SeaTech optical transmissometer (measuring light transmission loss over a 25-cm path-length). Four 10-liter water bottles (Teflon-coated Niskin bottles) collected water samples at designated depths (benthic boundary layer, optical transmission minima and maxima and in the surface mixed layer) that were observed during the CTD downcast. A total of 118 CTD stations were made in the Kara Sea during EPOCA-95 (figure 3.3).

3.1.4 Surface and Ice Drifters

We deployed a total of 19 ARGOS tracked Russ Davis-style surface drifters, manufactured by Met-Ocean. Unfortunately all failed within the first 50 hours after deployment. We also deployed three ice-beacons on a special mooring arrangement. Due to the unusually warm summer and fall, there was no sea ice of icebergs present within the Kara Sea. We arranged the ice beacons with flotation to support them high in the water and provided a dragging anchor to prevent large movement until they could be frozen into the ice. This anchor consisted of light parachute cord and a piece of chain on the bottom. As of the writing of this document, the arrangement appears to be working.

3.2 Distribution Coefficient Experiment

Distribution coefficients (K_d's) are important parameters used to model the dispersion of radionuclides released from Kara Sea nuclear waste dumping grounds. They are defined as,

$$K_d = A_{sed} / A_{sw},$$

where for a given parcel of water, A_{sed} is the activity (Bq/kg) of a radionuclide attached to particles and A_{sw} (Bq/kg) is the activity of a radionuclide dissolved in seawater. Distribution coefficients are themselves functions of several variables, including sediment concentration and character, pH and dissolved organic matter concentration. The majority of distribution coefficients currently used by numerical modelers in contaminant transport models were derived from controlled experiments conducted in laboratories. These laboratory experiments are unable to reproduce conditions in the natural environment and thus are only marginally reliable for predicting contaminant transport behavior. An experimental protocol was designed for the EPOCA-95 expedition to measure K_d's on site at many locations throughout the Kara Sea. To our knowledge, this investigation is the first time such an approach has been employed. Thus the results of this investigation will not only aid in the evaluation of the risk to human health and the environment posed by dumped nuclear waste, but will also contribute an improved methodology for determining realistic environmental K_d values.

The approach employed was to collect 10 liter water samples by deploying Niskin bottles attached to a CTD rosette. Water samples were retrieved from two to four depths at thirty-four locations in the Kara Sea. The areas emphasized were the mixing zones of the Ob and Yenisey, the Kara Gate, the Novaya Zemlya Trough and the shelf break at the edge of the river delta. In all, 108 samples were retrieved and processed during the expedition.

A 250 ml subsample from each 10 liter water sample was placed in a polypropylene bottle and refrigerated at 0-3° C. All samples collected within the previous 48 hours were then spiked with 10 kBq ^{241}Am, 10 kBq ^{134}Cs and 5 kBq ^{57}Co inorganic. ^{134}Cs was used as a proxy for ^{137}Cs and ^{57}Co was used as a proxy for ^{60}Co. The samples were then stored in the refrigerator for five days. After five days, each sample was filtered through 0.2 μm, 47 mm Nuclepore filters to

separate the sediment from the water fraction of the sample. The filter and a 30 ml subsample of water are being returned to the IAEA-MEL where they will be analyzed by gamma spectrometry to determine the concentration of each radionuclide on the filter and in the water. This data, along with sediment concentrations will be used to calculate K_d's for all 108 samples. Sediment concentrations at each station depth were determined by filtering 1-3 liters of water from the 10 liter sample through preweighed 0.2 μm, 47 mm Nuclepore filters. The filters will be returned to the IAEA-MEL, dried and reweighed to determine the net sediment concentration on each filter. This large data set for K_d's will provide risk assessors and radionuclide transport modelers with information to define the relative importance of sediment and water transport pathways for the radionuclides, ^{241}Am, ^{137}Cs and ^{60}Co.

3.3 Radiological, Chemical and Geological Sampling and Characterization

An important objective of this research expedition was to retrieve water and sediment samples for radionuclide and chemical analyses in order to identify the predominant sources of radionuclide and chemical contamination in the Kara Sea.

3.3.1 Sediment Sampling

3.3.1.1 Box Corer

The sediment box corer is a Ocean Scientific minicorer with a scissor arrangement for the spades. The successful operation of the box corer depends upon the box core frame impacting the sea floor squarely. The spade closure is actuated by a 'no-load' release mechanism. After penetration of the sediment, the spade scissors close off the top and bottom of the corer when the trigger cable is taken up by the ship winch. A relatively undisturbed core of the sea floor sediment is thereby enclosed by the box corer during the ascent through the water column and delivery onto the deck of the ship. A core of sediment, 19 cm x 19 cm in area and extending a maximum of 50 cm in depth (the depth depends on the texture and cohesion of the sediment), yields supernatant water and a minimally disturbed sediment with its biological, chemical and geological structure intact.

Sediment subcore samples were removed for radioisotopic analyses and physical property measurements. Two subcores (8.2 cm diameter, 36 cm long) were collected for radioisotopic analyses at NRL-DC and the IAEA, one subcore (6.1 cm diameter, 13 cm long) was taken for physical property measurements. The remaining exposed surface sediment was sampled by scraping the surface layer of the core. Two samples were obtained for chemical analyses (including PCBs, and heavy metals), one for surface radiological analysis by NDRE, one for on board K_d experiments, one for laboratory K_d experiments and one for ^{129}I analysis.

The radioisotope subcores are sectioned at 1-cm intervals to a depth of 10 cm, then slices at 12-13 cm, 15-16 cm and 18-19 cm depths, frozen in separate plastic bags, and transported in

dry ice to the laboratory for analysis. Physical property subcores are capped, taped, and transported intact to the laboratory for analysis.

Preliminary gamma ray analysis was conducted on board using NaI spectrometers. Post cruise analysis at NRL, IAEA and NDRE will be performed in the laboratory using high-resolution germanium diode gamma-ray detectors in a shielded low-level radio assay facilities which will provide much greater sensitivity and specificity of the gamma-ray emitting nuclides in the samples. The IAEA intends to analyze the sediment samples for plutonium as well.

3.3.1.2 Grab Samplers

Two grab samplers were used to when collection by the box corer was not possible due to sea state or mechanical problems with the box corer. One corer was of clam shell design and the other used a dual spade design. The grab sample taken with these cores were mixed with little of the top one to two cm layer remaining. The samples taken from the grab were the same as the surface samples from the box core listed above.

3.3.2 Physical Characterization of the Sediment

Subcores of the top 12 cm of sediment were colledted for physical characterization. Initially the water content, bulk density, vane shear strength and porosity and void ratio will be measured. If further funding is available, grain size, specific gravity, Atterberg properties, hydraulic conductivity, compressibility, consolidation history and clay microfabric properties will also be measured.

3.3.3 Chemical Analysis of Sediments

NDRE will analyze the surface samples for PCBs and heavy metals.

3.3.4 ^{129}I Samples

One liter water samples were taken at two to four depths at each station where Niskin bottle samples were taken. These samples will be analyzed by Linus Killius of the University of Toronto Isotrace Laboratory using accelerator mass spectrometry. The sampling stations and depths are listed in Table 4.3.

3.3.5 Carbon Analysis Samples

Particulate matter suspended in the water column of the Kara Sea are derived from three main sources. Clastic sediments derived from continental run-off from Novaya Zemlya, sediments discharged from the Rivers Ob and Yenisey and particulate matter derived from biological production in the surface waters of the Kara Sea. Inorganic and organic carbon analyses will be performed on sediments filtered from water samples collected for the K_d

experiments. One to six liters of water from each sample depth were filtered through precombusted, Whatman GF/F 25 mm filters. These filters containing particulate matter extracted from the water samples will be returned to the IAEA-MEL to determine percent carbon in each of the samples. Both inorganic and organic carbon content will be determined by cHN analysis. This information will not only provide a greater understanding of the biogeochemistry of Kara Sea waters but will aid in the interpretation of the experimentally-determined K_d values. The stations at which samples were taken are listed in table 4.3.

3.3.6 Large Volume Water Samples

Large volumes of surface and bottom water were sampled in the Kara sea in order to determine the concentration levels of ^{137}Cs, ^{90}Sr and Pu in sea water. The samples were acquired using an underwater pump and hose. Two samples were typically acquired per station. One from 5 m below the surface and the other from 5 to 20 m above the sea floor.

Approximately 100 l of sea water was the amount needed for determination of ^{90}Sr activity. Sea water was pumped into the large containers and filtered simultaneously as the container was filled with water from the sea. Sea water was filtered through a 0.3 μm filter in order to separate particles from sea water and the filtered sea water were transferred to 30 l containers.

The samples for the IAEA were stored without further treatment. Sr carrier (125 mg Sr/ 30 l) and 250 ml concentrated HCl preservative were added to the sea water samples for NDRE. ^{85}Sr tracer (1000 Bq/ 30 l) was added to determine the chemical yield of the following separation procedure. Filters and sea water were stored and will be subjected to further treatment in the laboratories. Separation and determination of ^{90}Sr will be carried out by NDRE and IAEA.

About 1500 liters of sea water was needed for determination of ^{137}Cs activity. Large containers were filled with sea water that was pumped through a 0.3 μm filter in order to separate particles from sea water. Sea water was then subjected to a following filtration through a filter bed containing silica gel impregnated with cupricferrocyanate ($CuFe(CN)_6$) to remove Cs from sea water. Cs was removed from sea water as a result of formation of a Cs - $CuFe(CN)_6$ complex. Filtration was carried out with a flow rate of 4 - 7 l/min depending on the particulate concentration in sea water.

The chemical yield of the complexation will be determined from a tracer experiment. ^{134}Cs tracer (15 kBq/ 1500 l) was added to containers while filling up 1500 l of sea water. Sea water with high and low concentration of particulate was subjected to prefiltration and filtration respectively. The ^{134}Cs concentration in the prefilter and the silica gel filter will be determined. This procedure was carried out in order to the determine the complexation rate of Cs with $CuFe(CN)_6$. The complexation rate of Cs in the silica gel filter is expected to be about 50 %. The concentration of ^{137}Cs in sea water samples will be determined from γ-spectrometry analysis of

^{137}Cs on the prefilter and silica gel filter of each sample after correction for chemical loss of Cs in the complexation procedure.

Preliminary measurements of ^{137}Cs in silica gel filters were carried out by NRL on board the ship. Determination of ^{137}Cs concentration in sea water samples will be carried out in the laboratories of NRL and NDRE. Post-cruise, the particulate filters will be ashed. The residual sediments will be weighed and analyzed using gamma ray spectrometry. The Cs adsorption filters will also be analyzed. This data will provide an *in situ* measurement of the sediment concentration and the partition coefficient (K_d) which will be compared to the on-board laboratory experiments. The stations where these samples were acquired are listed in table 4.3.

3.3.7 Plutonium, Strontium, and Cesium Analyses

Ninety liters of water were collected from the surface and at depth at thirteen stations in the Kara Sea. The samples were filtered through a 0.3μm Millipore filter cartridge to remove particulate matter and stored in 30 liter containers. These samples will be returned to the IAEA-MEL to determine the levels of plutonium, strontium and cesium in the samples. The chemical separation procedure provides for the extraction of all three radionuclides from a single water sample (see figure 3.4). Once the precipitants containing the radionuclides of interest have been extracted and purified, the activities of each radionuclide will be determined using standard radionuclide measurement procedures.

3.3.8 Tritium

One-liter water samples were collected from Niskin bottles deployed by the CTD rosette at six stations in the Kara Sea. A total of nineteen samples were collected. These samples will be analyzed for tritium by distillation and low level liquid scintillation counting. The stations at which tritium samples were taken are given in Table 4.3.

3.3.9 On-board Radioassay

On-board analysis of the samples was performed using two Harshaw 5.08 cm thick by 12.7 cm diameter NaI scintillator spectrometers coupled to individual APTEC amplifier/ ADC/ multichannel analyzers on circuit boards in two 486/66 MHz PCs. One of the detectors was mounted inside a small lead shield. This shield provided 1 to 2.54 cm of lead around the detector. The total count rate in this detector was 30% of the unshielded detector. These systems provide an energy spectrum of gamma rays from the sample and enables the identification of specific isotopes from observation of their characteristic gamma rays at specific energies. A second computer board in each system provide preamp power and high voltage to the spectrometer. This system provided a quick look at the samples on board. The detectors were calibrated in the laboratory and on board with ^{137}Cs sources. The detector efficiency at 661 keV is approximately 8% for the 1 cm sediment slice. This efficiency is used to calculate the activities reported. Note that this efficiency was approximate. The sources

used were not NIST traceable standards, attenuation effects of the sample medium and the geometry for the Cs water filters was not considered and significant dead time corrections were needed as a result of the high calibration source activity. The numbers given in this report should not be compared to any final results reported elsewhere. Another important factor affecting the quality of this data set was the K_d experiments underway in the adjacent laboratory. Variable backgrounds, especially the changes in ^{134}Cs activity made the data from the unshielded detector unreliable and added uncertainty to the spectra analysis of the shielded detector. All the data reported here were taken with the shielded detector. The unshielded spectrometer was used for radiation protection swipe analysis and for verification of the K_d protocol.

Energy spectra from the ^{137}Cs adsorption filters from the large volume water samples were acquired for 12 to 24 hours per sample. We also measured the spectra of a few top layer sediment core slices from near the barge position. The spectrum was normalized to and subtracted from a 48 hour background spectrum. The residual spectrum was analyzed for additional peaks.

3.4 RADAM

One of the goals of the NRL monitoring project is the development of a monitoring station capable of year long deployments in Arctic seas, the acquisition of gamma ray spectroscopic data during that period and the transmission of that data back to the laboratory. We have design a station that is currently being procured. The sensor selected is produced by a Norwegian company, Oceanor. The RADAM detector is an low power, integral 7.62 x 7.62 cm NaI scintillator with PMT, power supply, electronics and multichannel analyzer. In order to better calculate detector sensitivity, NDRE borrowed an early prototype version of the RADAM from Oceanor. This detector was tethered on a 100 m cable. Background spectra were measured at two stations. One surface (10 m deep) station near Stepovogo Bay and the second station with the sensor in contact with the bottom sediment off the Yenisey river. The data was collected in 1024 channels and transferred via serial communication to a laboratory PC.

3.5 Radiological Protection

Two radiological protection plans were drawn up and implemented to insure the safety of personnel and crew during the sampling operations (see Appendix 1) The first plan was to insure that no radiological contamination would occur during sampling from the sea bottom. This plan was reviewed by the Safety Office of the U.S. Naval Research Laboratory. Prior to commencement of operations all personnel were briefed on the possible radiation hazard and the details of the radiological protection plan. TLD dosimeters were distributed to all personnel and pocket dosimeters given to personnel who would most likely be exposed to any sources of radioactivity. Upon completion of the cruise the TLD dosimeters were collected and will be returned to NRL to be read. The personnel dosimetry report will then be forwarded to all participating organizations.

The samples from the sea floor were monitored for x-ray, γ-ray, β particle, α particle and neutron emission as needed. Prior to operations, the detectors were checked using a Coleman lantern mantel which contains radioactive thorium and is useful as a low-level unregulated radiation source. The primary instrument used was a Ludlum Model 2350 Data Logger with a 2.54 x 2.54 cm NaI probe (for γ-rays), a Geiger/Muller tube probe (for x-rays, γ-rays, and β particles), and a scintillator probe (for α particles.) In addition a Ludlum Model 12-4 Bonner sphere type neutron monitor was used. TLD dosimeters were also placed in key areas such as on the fan-tail A frame, in the wet lab, in the hold and in the wet/dry lab as area monitors for the entire operation.

When a sample was first brought up, it was surveyed while still suspended over the side of the ship using the NaI gamma-ray probe attached to a long pole. After determining that the sample was not an immediate radiation hazard, it was brought on-board where a second survey was made for 60 seconds using the thin window Geiger/Muller tube probe in direct contact with the sediment. The neutron monitor was also placed along side the sample during this same time period. Two to three filter paper swipes were taken from the surface of the sample and measured for a 600 second counting time using the α scintillator probe. In addition, individual objects brought up such as rocks or wood were also checked using both the Geiger/Muller tube probe and the α scintillator probe.

The second plan (see Appendix 2) covered the handling of radioactive tracers used in experiments conducted on board the ship. This plan was again reviewed by the Safety Office of the U.S. Naval Research Laboratory. In addition the plan for the experimental protocol was submitted to the Norwegian Radiation Protection Authority for approval prior to the expedition. All radiation work conducted onboard the H.U. Sverdrup II was conducted in accordance with the approved safety plans.

Radioactive sources used on board ship are listed in table 3.1.

Table 3.1 Radioactive Sources

Source	Activity	Medium
^{134}Cs	100 kBq	100 ml aqueous sol.
^{85}Sr	500 kBq	1 l aqueous sol.
^{134}Cs	1.0 MBq	5 ml aqueous sol.
^{57}Co	0.6 MBq	1 ml aqueous sol.
^{241}Am	1.0 MBq	1 ml aqueous sol.

The first two sources in the table were used by NDRE to determine the collection efficiency of the large volume water sampling system. The ^{134}Cs source was used in two calibration runs by mixing the tracer with 1600 l of seawater and processing the water using the standard techniques. For each 90 l seawater sample taken for Sr analysis 15 ml (7.5 kBq) of the ^{85}Sr solution was introduced into the water sample as a tracer of the chemical processing. The other three sources were used by in the on board K_d experiments. Each sea water sample was spiked with 5 kBq of ^{57}Co, 10 kBq of ^{134}Cs and 10 kBq of ^{241}Am. All sources were stored in a locked chemical locker. The maximum dose rate external to the locker was 4 mR/hr. All areas where radioactivity was stored or used were marked and restricted to limited access. All uses of the tracers were monitored by the radiation safety officer and were only performed when the sea state permitted safe handling of the solutions.

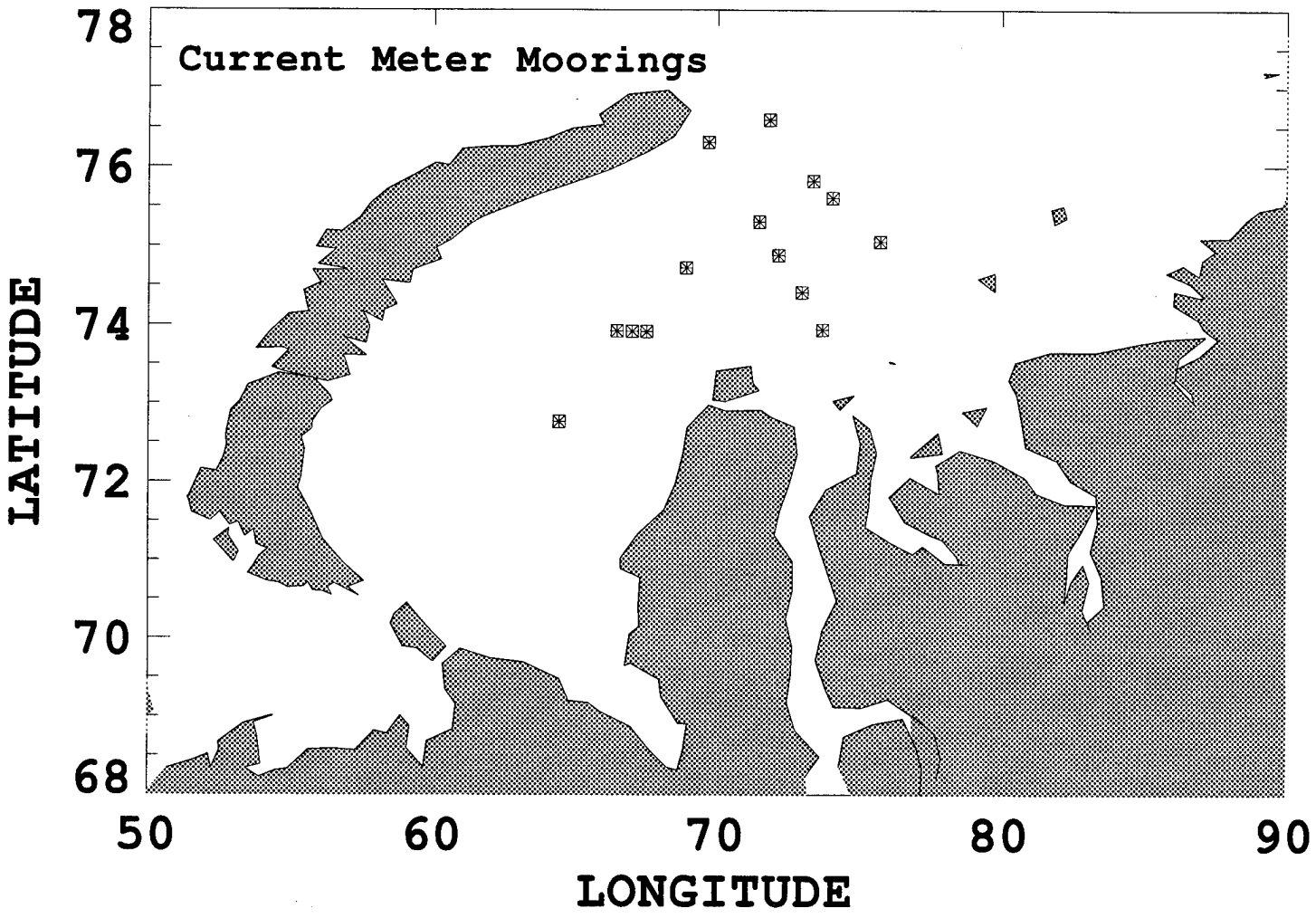


Figure 3.1 Current meter mooring locations. These 14 rigs were recovered after 2-3 weeks of operation.

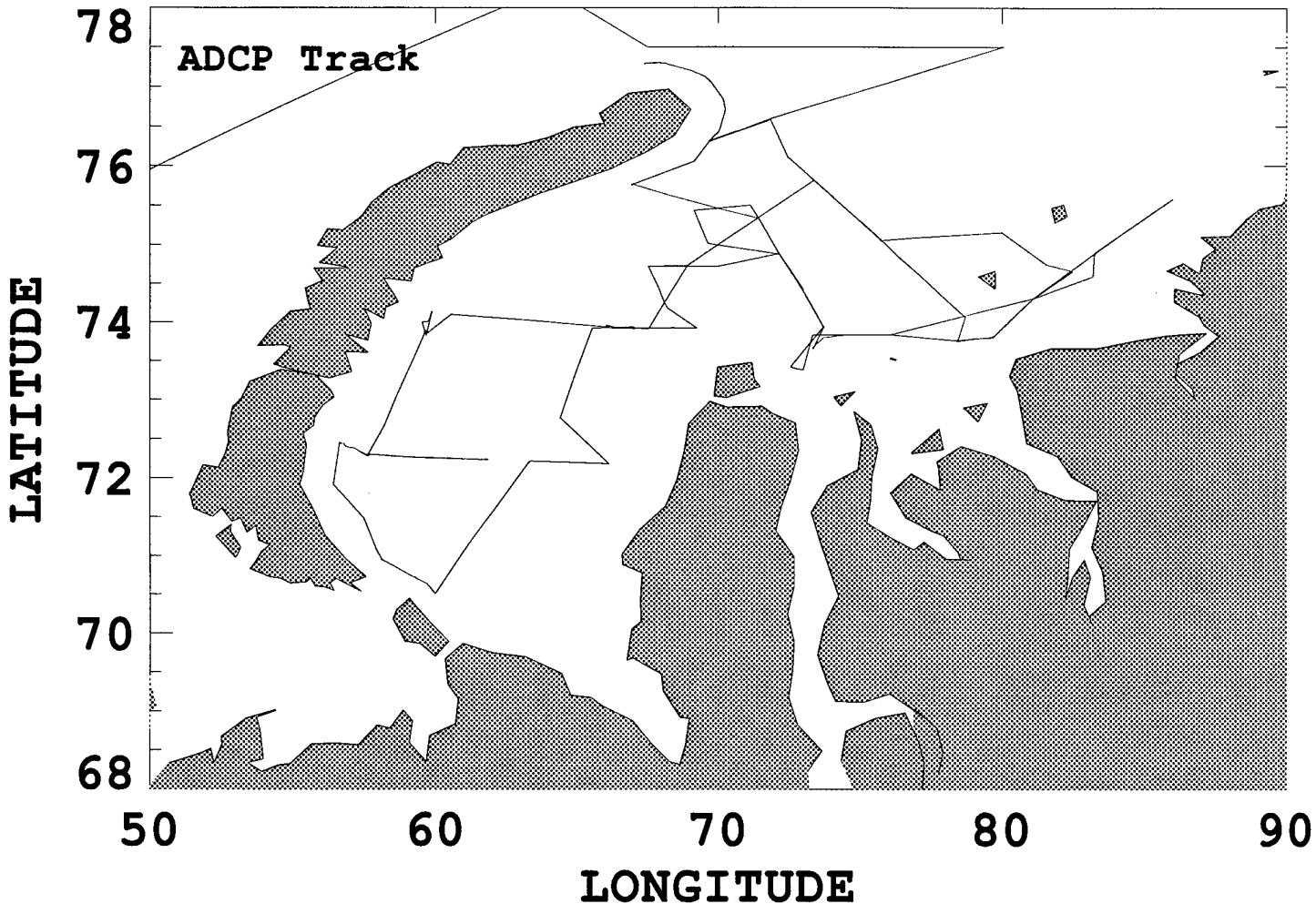


Figure 3.2 Ship track during ADCP observations. Note entrance and exit around north tip of Novaya Zemlya, concentration of effort along river entrances and along delta edge, and extensive work in the southwestern part of the Kara Sea.

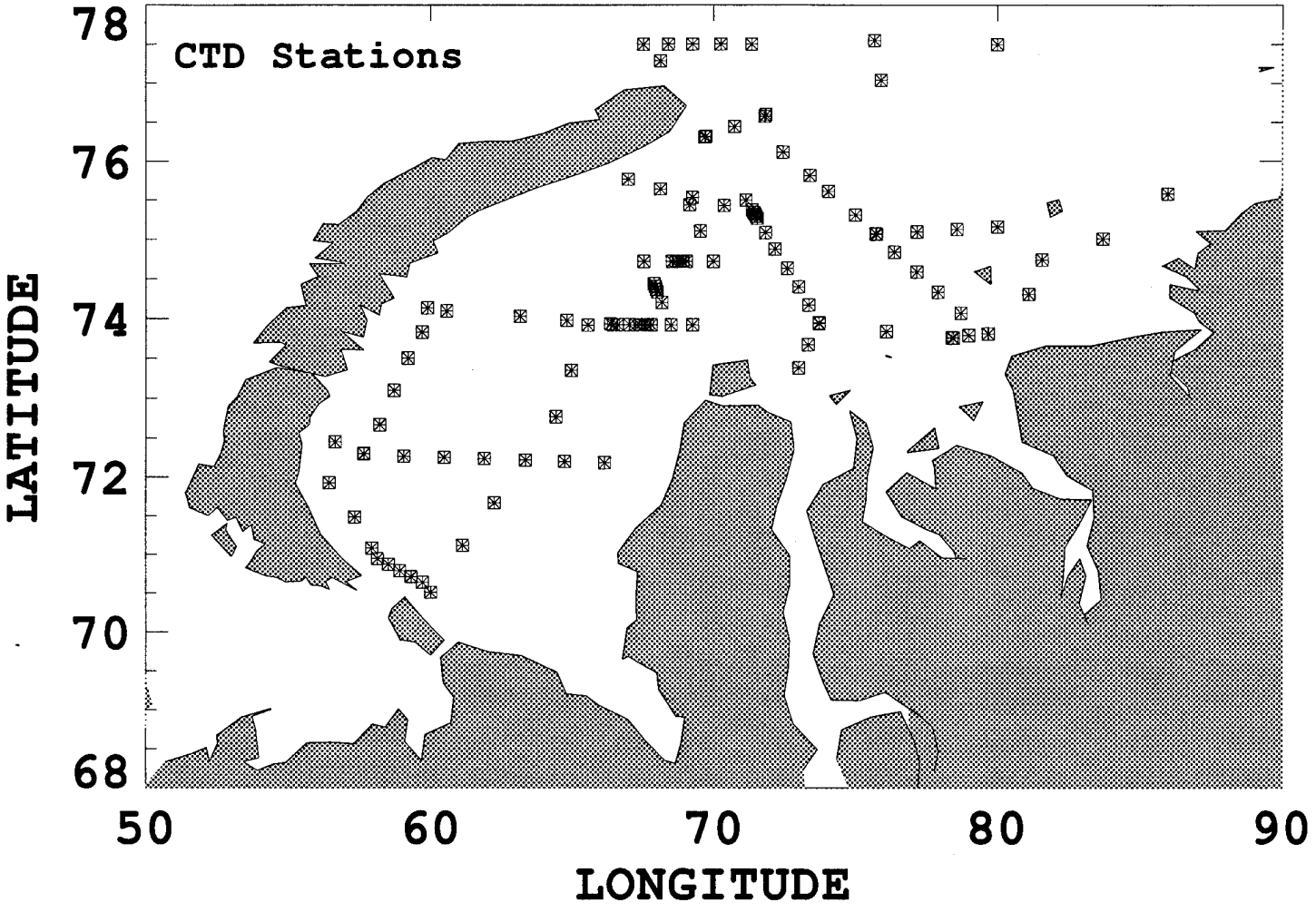
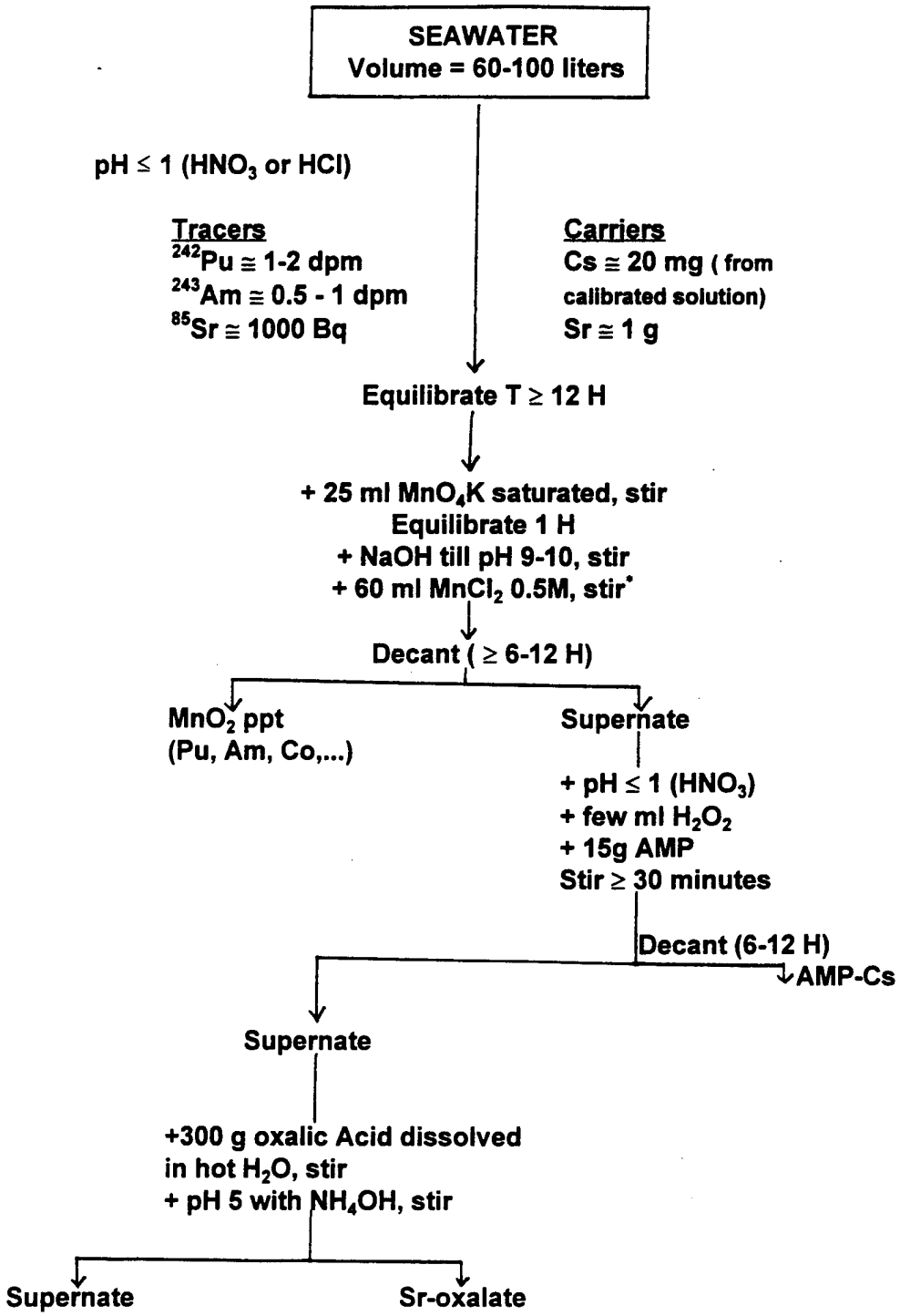


Figure 3.3 Location of hydrograhpic stations with CTD casts.

SEQUENTIAL ANALYSIS OF Cs, Sr, Pu and Am IN SEAWATER



* purple color should disappear. $Mn(OH)_2$ precipitates with color brown-green, if not, add 10 ml (or more) $MnCl_2$, check, maintain pH ≥ 9.

Figure 3.4 Radionuclide analysis of seawater samples.

4.0 ACCOMPLISHMENTS / PRELIMINARY RESULTS

A list of the major accomplishments is given in table 4.1. Stations where radiological or chemical samples were taken either from the water column or the sediment are shown in figure 4.1 and table 4.2. The areas of concentration included the Novaya Zemlya trough, the frontal zone between the riverine dominated Yamal plateau and the trough region, and the Ob/Yenisey river region. An inventory of the radiological and chemical water column samples taken during the CTD and full environmental stations is given in table 4.3 and for sediment samples in table 4.4.

4.1 ^{137}Cs Analysis

The results of the on board spectral analyses are summarized in table 4.5. All activities are reported in Bq/kg for sediment samples and Bq/1000 liters for water analysis. The sediment samples are reported per kg of wet weight. The sediment activities from the final analysis will probably double when reported per dry sample weight. The geometric or attenuation effects have not been taken into account and will also change the results. These values should be used for a relative comparison and not for comparison with any other data set. An additional uncertainty in the preliminary data is the variability of ^{214}Bi in the sediment spectra. With a γ-ray peak at 609 keV the changing activities of ^{214}Bi interferes with the analysis of the ^{137}Cs peak at 661 keV. This problem is eliminated in the laboratory by using higher resolution detectors. Analysis of the sediment samples is also difficult because of the small sample size. Again in the laboratory longer measurement times will improve statistical uncertainty. One final complication to the analysis was the use of ^{134}Cs tracers in the adjacent laboratory. These variable activity of ^{134}Cs in the spectra made background subtraction difficult.

For the sediment samples the 3σ minimum detectable activity is 6 Bq/kg for the typical sample size. The 2σ statistical uncertainty in the sediment analysis is approximately 20%. However, analysis in the laboratory with much greater sensitivity and much lower background will yield accurate values of the ^{137}Cs activity for all the samples, as well as other isotopes which may be present at low activities.

The preliminary results for ^{137}Cs activity in the water column are shown in figure 4.2. The activities shown given in Bq/1000 l and are normalized by the actual volume of water filtered which was approximately 1600 liters. ^{137}Cs activities from these samples are estimated to be in the range of 1-10 Bq/1000 liters. The 2σ statistical error is 5-6%. These values are consistent with the 1992 Russian-Norwegian cruise data. The preliminary results show a clear trend of higher activity levels in the deep samples compared to the surface samples. However, the final determination of the magnitude awaits laboratory analysis and the determination of extraction efficiency.

4.2 RADAM Analysis

Spectra from the RADAM detector are given in figure 4.3 for the surface measurement near Stepovogo bay and in figure 4.4 for the bottom measurement near the Yenisey river. The surface sediment was acquired for 14 hours and the bottom sediment for 9 hours. The background count rate for the ^{137}Cs peak region is 0.0020 cps/keV for the surface measurement and 0.0035 cps/keV for the bottom measurement.

4.3 Oceanography

Track lines, station positions and mooring locations have been presented in Figs. 3.1-3.3. Figure 4.5 shows the near surface (5 m depth) salinity field measured during EPOCA-95 at the hydrographic stations. Referring to Fig. 4.5, it is apparent that the fresh water mass from the river outflow is not as extensively distributed over the delta area, nor is the salinity as low in the river entrances as it was during 1994. This would indicate that the outflow during the 1995 summer season was not as large as during 1994. Near surface temperatures (not shown) over the whole sea, were higher than during the previous year, also indicating a warmer summer and later-occurring transition season. Higher salinity water dominates the southwestern Kara Sea, suggesting a strong inflow of Norwegian Atlantic Water through the Kara Gate. Some penetration of Barents Sea/Atlantic Water can be seen around the northern tip of Novaya Zemlya although the northeastern coast of Novaya Zemlya appears to be dominated by fresher river-origin waters.

Figure 4.6 shows a gridded version of ADCP current observations at a depth of 15 m. This depth is at the top of the strong halocline. Since semi-diurnal tidal currents are a dominating feature of flow in the Kara Sea, sub-tidal currents were obtained from the ADCP by a running box-car average over 12.5 hours. Although ADCP observations must be taken in the context of a "snapshot" look at ambient flow, Fig. 4.6 shows some surprising results. Instead of a counter-clockwise gyre in the western Kara Sea, as given in Russian Atlases, a clockwise gyre is clearly evident. As also observed during the 1994 cruise, the dominant flow is northward along Novaya Zemlya. Strong inflow is also seen from the Kara Gate. River flow is northward and westward, although the relatively deep first "good" measurement by the ADCP may have put it into the range of the estuarine inflow on the eastern side of the rivers, where return flow is evident.

Figure 4.7 shows an example of bottom currents obtained by the moored instruments. These were averaged over the entire records but terminated at a complete whole tidal cycle. Very weak currents are shown over the delta, but surprisingly, fairly substantial currents are apparent in a northeastward outflow from the trough area. Our investigations will pursue the possibility of these outflows to connect with the St. Anna Trough.

Figure 4.8 shows a combined hydrographic/ADCP section across the Kara Gate. This was an important region because of its influence as a port and boundary condition for both numerical and laboratory models of the Kara Sea. Since we could not moor instruments in the Kara Gate,

we were particularly pleased with the good results of the combined hydrography/current mapping. This section shows an influx of warm, fresh water with a core depth of about 50 meters. The warmth is definitely indicative of Norwegian coastal waters. The lower salinity is indicative of strong contributions from the Pechora and other coastal outflow waters.

TABLE 4.1 ACCOMPLISHMENTS	
ADCP/Bathymetry Transits	6120 km
Current Rigs Deployed for Cruise	14
Current Rigs Deployed for Year	3
CTD Stations	118
Small volume water sampling stations	34
Large volume water sampling stations	19
Sediment sampling stations - Grab samples	8
Sediment sampling stations - Box corer	19
RADAM stations	2

Table 4.2 Environmental Stations

1995 KARA SEA STATIONS

EPOCA 1995

station	latitude			longtitude			series	station	longtitude	latitude
	deg	min	dec deg	deg	min	dec deg				
501	77	7.5	77.13	68	7	68.12	1	501	68.12	77.13
502	76	18.5	76.31	69	40.8	69.68	2	502	69.68	76.31
505	75	48.9	75.82	73	23.7	73.40	3	505	73.40	75.82
509	74	50	74.83	76	22.9	76.38	4	509	76.38	74.83
513	73	45	73.75	78	27.6	78.46	5	513	78.46	73.75
515	73	48.1	73.80	79	40.5	79.68	6	515	79.68	73.80
519	75	34.5	75.58	85	57.8	85.96	7	519	85.96	75.58
520	73	50	73.83	76	5.62	76.09	8	520	76.09	73.83
521	73	22.6	73.38	73	0	73.00	9	521	73.00	73.38
523	73	56	73.93	73	43.2	73.72	10	523	73.72	73.93
526	74	37.9	74.63	72	36.1	72.60	11	526	72.60	74.63
534	75	29.9	75.50	71	8.2	71.14	12	534	71.14	75.50
5271	74	52.5	74.88	72	10.1	72.17	13	5271	72.17	74.88
5410	73	55	73.92	68	29.3	68.49	14	5410	68.49	73.92
5431	73	55	73.92	66	27.2	66.45	15	5431	66.45	73.92
5460	72	49	72.82	64	25	64.42	16	5460	64.42	72.82
5510	71	7	71.12	61	7.1	61.12	17	5510	61.12	71.12
5540	70	42.6	70.71	59	18.5	59.31	18	5540	59.31	70.71
5570	70	56.8	70.95	58	6.9	58.12	19	5570	58.12	70.95
5600	71	55.6	71.93	56	25.4	56.42	20	5600	56.42	71.93
5610	72	27	72.45	56	38	56.63	21	5610	56.63	72.45
5620	72	18.1	72.30	57	38.1	57.64	22	5620	57.64	72.30
5630	72	18.4	72.31	57	38.4	57.64	23	5630	57.64	72.31
5640	72	17.9	72.30	57	38.6	57.64	24	5640	57.64	72.30
5680	72	40.1	72.67	58	12	58.20	25	5680	58.20	72.67
5720	74	7.9	74.13	59	53.2	59.89	26	5720	59.89	74.13
5712	73	53	73.88	59	41	59.68	27	5712	59.68	73.88
5721	74	5.6	74.09	60	33.4	60.56	28	5721	60.56	74.09
5724	73	55.8	73.93	66	21	66.35	29	5724	66.35	73.93
5381a	74	43	74.72	68	53.8	68.90	30	5381a	68.90	74.72
5080	75	4	75.07	75	43.1	75.72	31	5080	75.72	75.07
5083	75	9.1	75.15	80	0.4	80.01	32	5083	80.01	75.15
5160	74	18	74.30	81	6.3	81.11	33	5160	81.11	74.30
5150	73	48.1	73.80	79	41.1	79.69	34	5150	79.69	73.80
5140	73	47	73.78	79	0	79.00	35	5140	79.00	73.78
5130	73	45.2	73.75	78	24.8	78.41	36	5130	78.41	73.75
5231	73	40	73.67	73	20.3	73.34	37	5231	73.34	73.67
5230	73	56.6	73.94	73	43.1	73.72	38	5230	73.72	73.94
5313	75	38.5	75.64	68	7	68.12	39	5313	68.12	75.64
5760	75	46	75.77	66	58	66.97	40	5760	66.97	75.77
5001	77	30	77.50	79	59.9	80.00	41	5001	80.00	77.50

Table 4.3 Water Samples

KARA SEA RADIOLOGICAL/CHEMICAL SAMPLE INVENTORY									
station	water depth	water samples(a) suspended sediment (c)	% organic & inorganic carbon	K_d	Tritium	I-129	Sr/Pu (c) IAEA	Sr (c) NDRE	Cs ext. (c)
501	406	6/41/389	three	three		three		5/ 387	5/ 387
502	134	7/121	two	two		two			
505	103	10/97	two	two		two			
509	35	5/28	two	two		two			
513	25	4/20	two	two		two	5/ 20	5/ 20	5/ 20
515	33								
519	54	4/14/40	three	three		three	5/ 40		5/ 52
520	20	3/17	two	two		two			
521	30	4.5/22	two	two		two	5 /25	5 /25	5 /25
523	24	5/18	two	two		two			
526	29	25	one	one		one			
5271	32	5/27.5	two	two		two			
534	220	7/241	two	two		two			
5410	28	5 / 25.5	two	two		two			3/ 27
5431	100	14 / 100	two	two		two			3/ 90
5460	59	6/ 29 / 53	three	three		three			
5510	80	7 / 98				two			
5540	200	24 / 88 / 195	three	three		three	3/ 180		3/ 180
5570	200	10 / 67 / 195	three	three		three	3/ 180		3/ 180
5600	290	5/ 25/ 150/ 187	three	three		four	3/ 280		3/ 280
5610	300	5 / 150 / 305	three	three		three	3/ 280		3/ 280
5620	350	10/ 175/ 332	three	three	two	three			
5630	355						3/ 320	3/ 320	3/ 320
5640	355	8.5/ 175 / 334	three	three		three	330		330
5680	370	5 /181 /360	three	three	three	three	3/ 350		3/ 350
5720	300	8/ 127/ 271	three	three	three	three	3/ 280		3/ 280
5712	344	7/ 110/ 220/ 329			four	four			
5721	375	9/ 124/ 251/ 366			four	four			
5724	98	5/ 19/ 86	three	three		three			
5381	45	5/ 21/ 40	three	three		three			
5080	41	5/ 37	two	two		two			
5083	44	5/ 12/ 39	three	three		three			

Table 4.3 Water Samples

KARA SEA RADIOLOGICAL/CHEMICAL SAMPLE INVENTORY									
station	*water*	*water samples(a)*							
	depth	*suspended*	*% organic &*	*K_d*	*Tritium*	*I-129*	*Sr/Pu (c)*	*Sr (c)*	*Cs ext.*
		sediment (c)	*inorganic carbon*				*IAEA*	*NDRE*	*(c)*
5160	39	4/ 12/ 36	three	three		three			
5150	33	4/ 12/ 28	three	three		three			3/ 31
5140	29	4/ 14/ 25	three	three		three			
5130	24	4/ 10/ 18	three	three		three			
5231	27	5 /12/ 23	three	three		three	3/ 27	3/ 27	3/ 27
5230	25	5/ 14/ 20	three	three		three	3/ 25		3/ 25
5313	333	21/ 162/ 317			three	three			
5760	280	4/ 139/ 263				three	3/ 250		3/ 250
5001	61	5/ 27/ 52				three	3/ 50		3/ 50
	notes:								
	a. water samples were generally taken at two to three depths using Nisken bottles								
	b. subcores were sliced at 1cm thicknesses from 0 to 10 cm, 12-13 cm slice, 15-16 cm and 18-19 cm.								
	c. depth of water samples								
	d. surface samples were taken with a clam shell grab sampler, a grey dredge sampler or the box core								

Table 4.4 Sediment Samples

			KARA SEA RADIOLOGICAL/CHEMICAL SAMPLE INVENTORY					
station	*sediment samples (b)*		*surface sediment samples(d)*					
	subcores		*I-129*	*organic*	*heavy metal*	*radio-*		
	radiological	*phys. sed. char.*		*contam.*	*contam.*	*nuclides*		
501			one	one	one			
502			one	one	one			
505			one	one	one			
509			one	one	one			
513			one	one	one	two		
515			one	one	one	two		
519								
520								
521	two	one	one/grey	one/grey	one/grey	two/grey		
523								
526			one	one	one	two		
5271								
534								
5410	two	one	one/box	one/box	one/box	two/box		
5431	two	one	one/box	one/box	one/box	two/box		
5460			one/box	one/box	one/box	one/box		
5510								
5540	two	one	one/box	one/box	one/box	two/box		
5570								
5600	two	one	one/box	one/box	one/box	two/box		
5610	two	one	one/box	one/box	one/box	two/box		
5620	two		one/box	one/box	one/box	two/box		
5630	two	one	one/box	one/box	one/box	two/box		
5640	two		one/box	one/box	one/box	two/box		
5680	two	one	one/box	one/box	one/box	two/box		
5720	two	one	one/box	one/box	one/box	two/box		
5712								
5721								
5724								
5381								
5080								
5083								

Table 4.4 Sediment Samples

			KARA SEA RADIOLOGICAL/CHEMICAL SAMPLE INVENTORY					
station	*sediment samples (b)*		*surface sediment samples(d)*					
	subcores		*I-129*	*organic*	*heavy metal*	*radio-*		
	radiological	*phys. sed. char.*		*contam.*	*contam.*	*nuclides*		
5160								
5150	two	one	one/box	one/box	one/box	two/box		
5140	two	one	one/box	one/box	one/box	two/box		
5130	two	one	one/box	one/box	one/box	two/box		
5231	two	one	one/box	one/box	one/box	two/box		
5230	two	one	one/box	one/box	one/box	two/box		
5313								
5760	two	one	one/box	one/box	one/box	two/box		
5001	two	one	one/box	one/box	one/box	two/box		

Table 4.5 Cs-137 Data

Kara Sea 137-Cs Activities				
date	*station*	*water (Bq/1000 l)*		*sediment*
		surface	*deep*	*Bq/kg*
30-Aug-95	501	10.2541	3.643195	
31-Aug-95	513	5.915329	8.778856	
31-Aug-95	519	2.963911	6.94	
2-Sep-95	521	6.598494	5.498959	
5-Sep-95	5410	4.442974	6.451371	
5-Sep-95	5431	3.088556		
8-Sep-95	5540	3.812102	3.047522	
9-Sep-95	5570	1.023255	5.487599	
9-Sep-95	5600	2.772742	5.132272	
9-Sep-95	5610	1.39109	4.17584	
10-Sep-95	5620			3.117664319
10-Sep-95	5630		3.5147	3.227699531
10-Sep-95	5640		4.789423	2.608242045
11-Sep-95	5680		4.416129	
12-Sep-95	5720		4.509796	
13-Sep-85	5431		2.490119	
16-Sep-95	5150		1.909377	
19-Sep-95	5230		2.349216	
19-Sep-95	5231		3.242616	

Figure 4.1 Chart of sampling stations.

PRELIMINARY COPY DRAFT #1

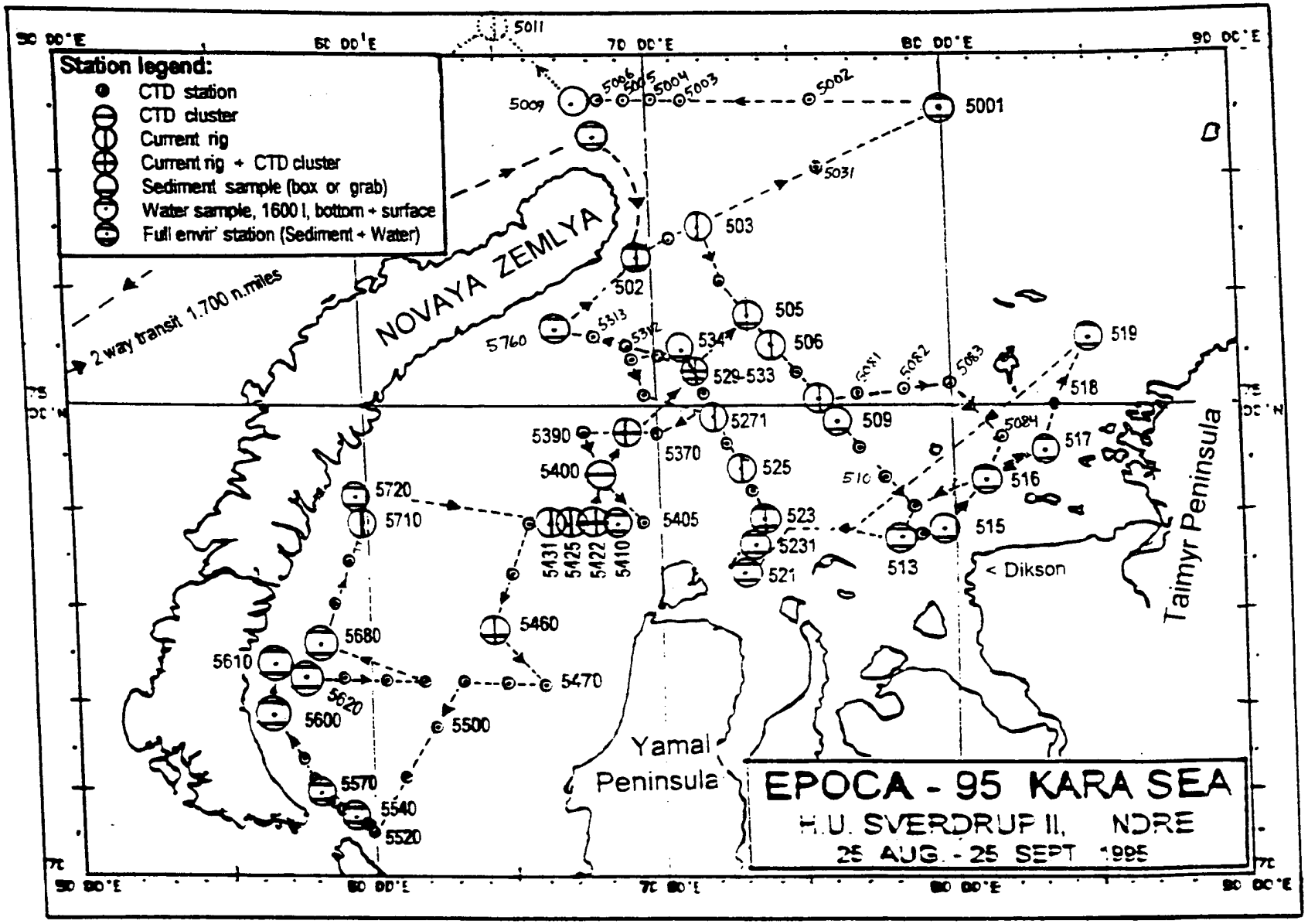
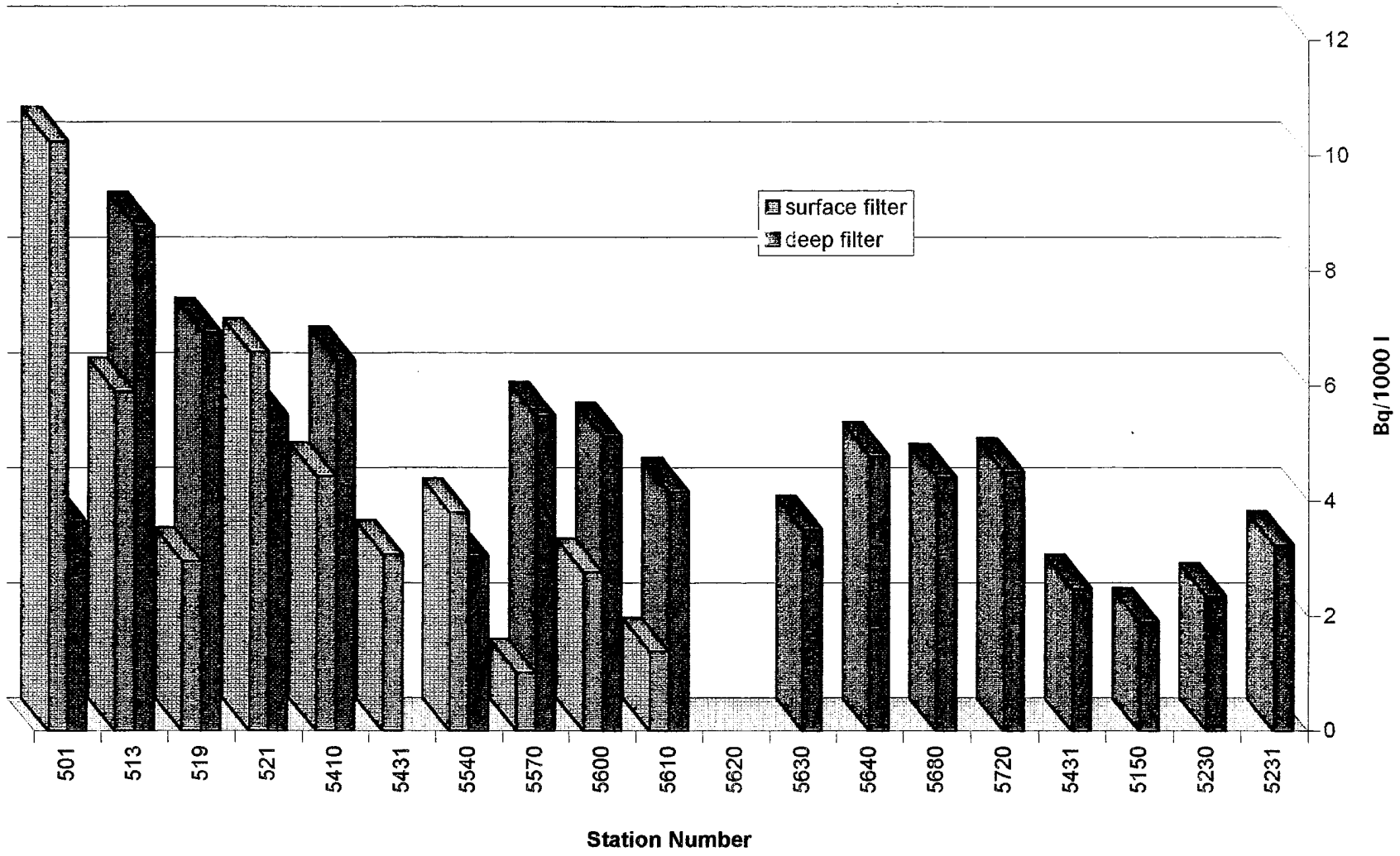


Figure 4.2 Cs-137 Activities in surface and deep water



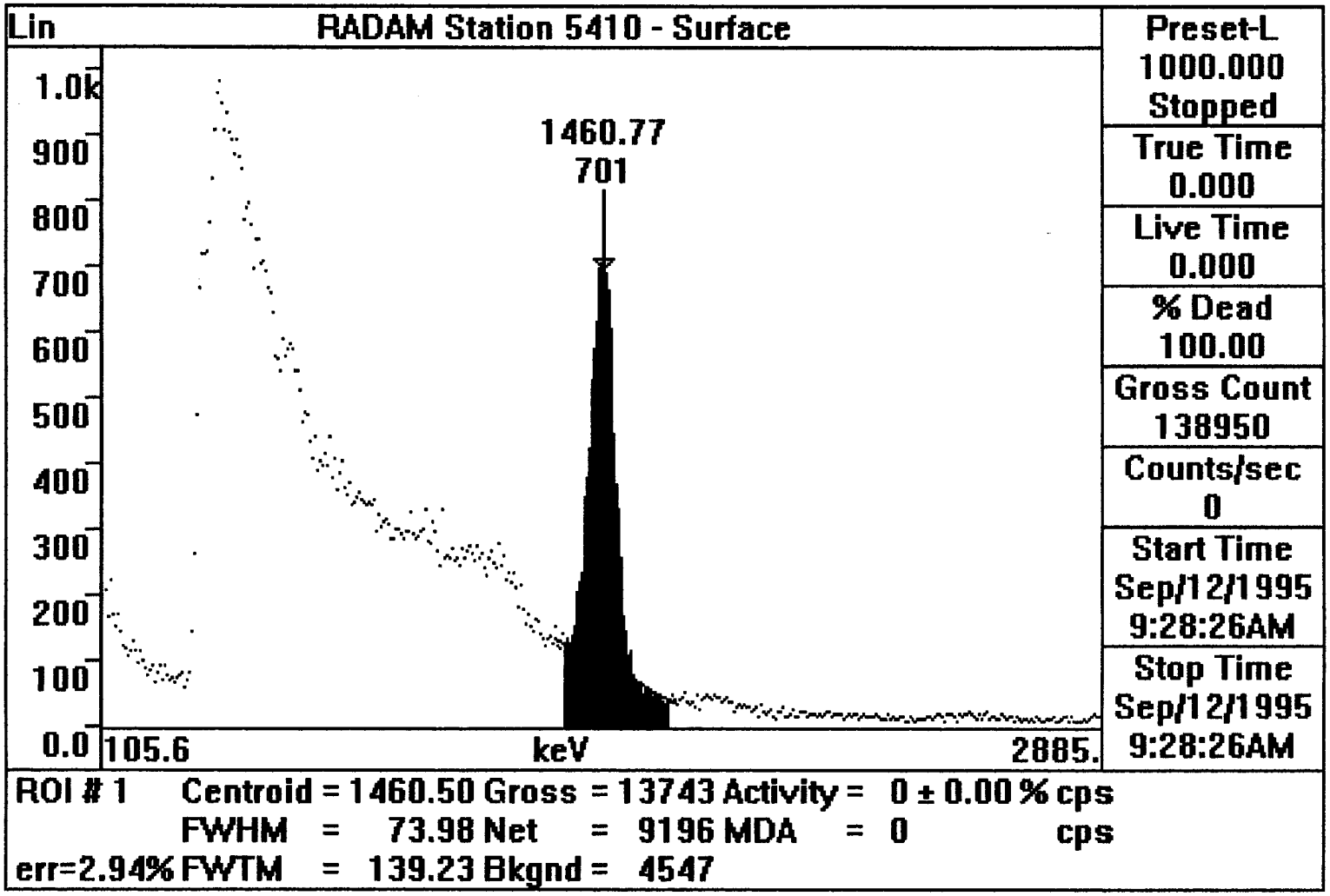


Figure 4.3 RADAM spectrum in surface water (10 m deep) near Stepovogo Bay acquired for 14 hours.

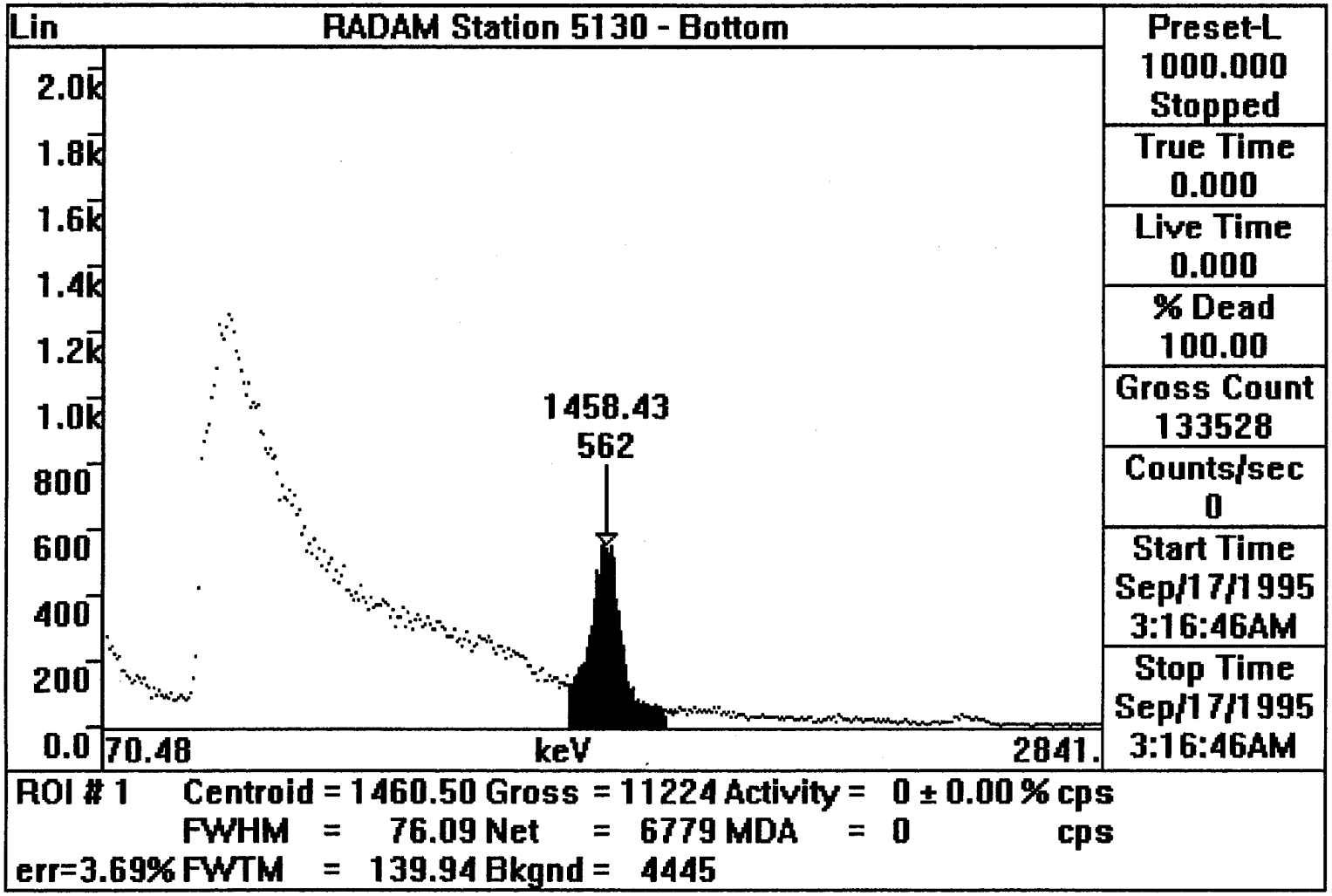


Figure 4.4 RADAM spectrum on sea floor near the Yenisey River acquired for nine hours.

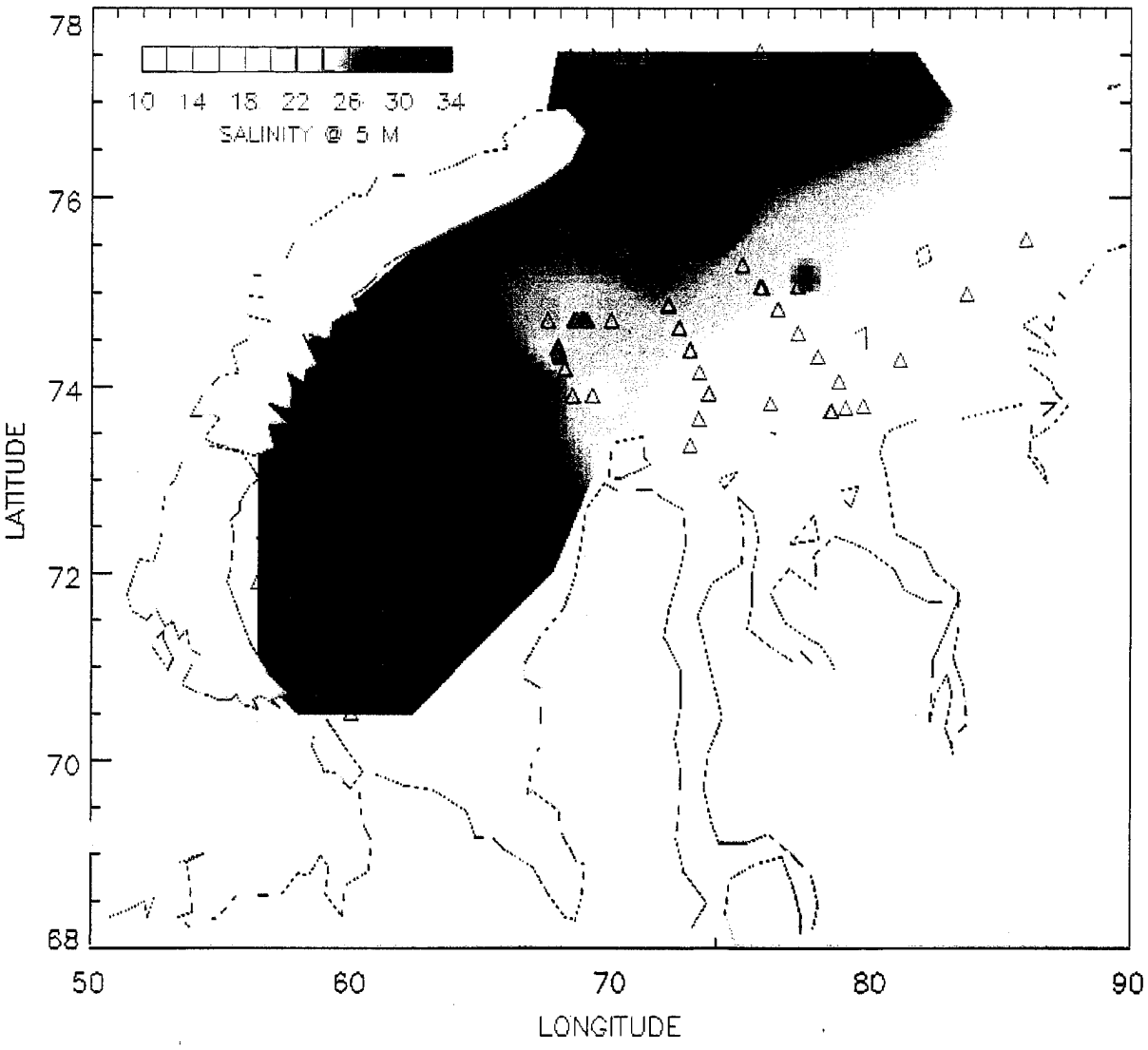


Figure 4.5 Salinity at 5 m depth as determined from CTD casts. Location of casts are given by blue triangles.

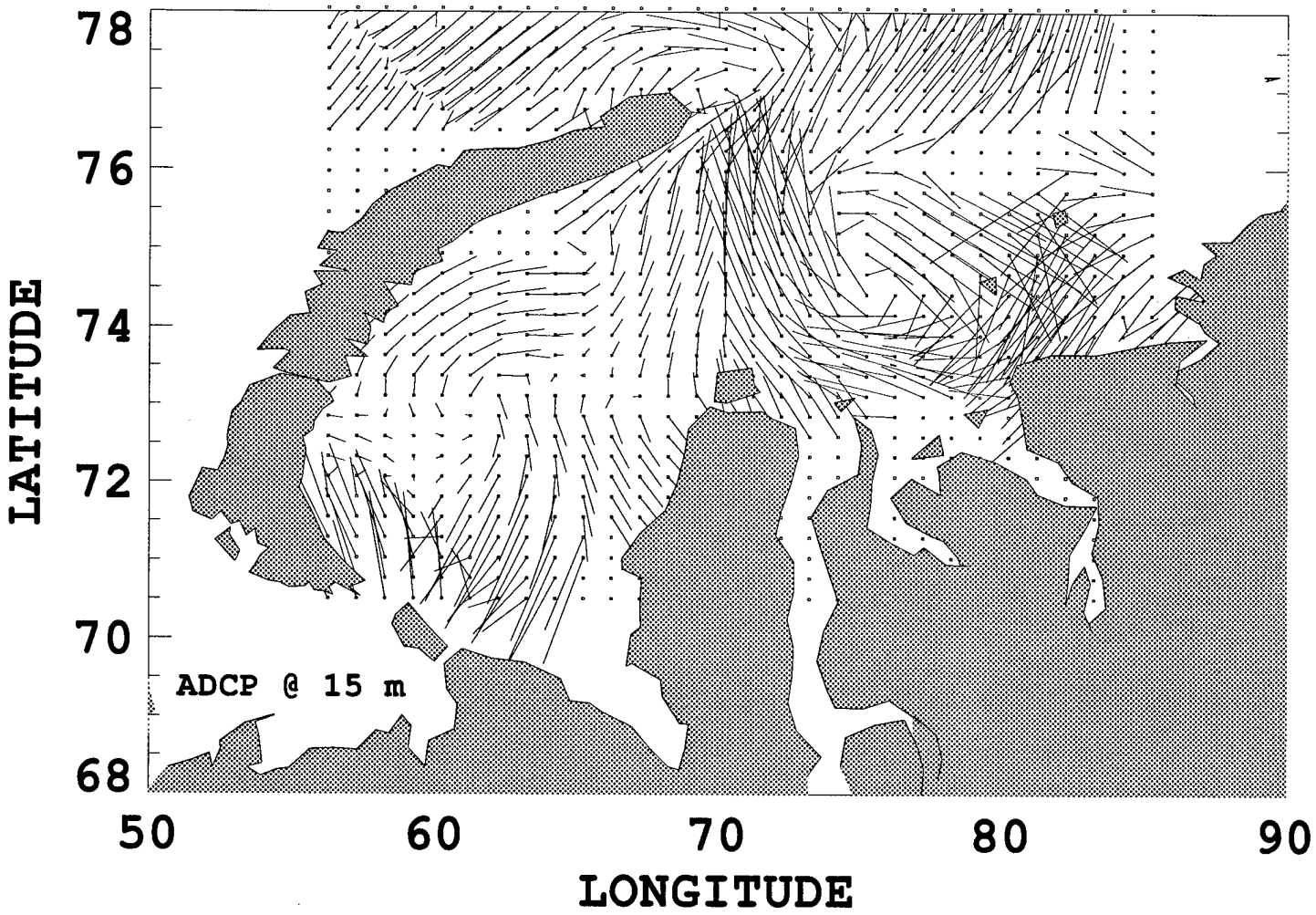


Figure 4.6 Current vectors derived from adcp observations at 15 m depth. "Foot" of vector and location of observation is given by a small dot. Current flow is away from this dot. As a scale, one degree of latitude is equal to 10 cm/sec current amplitude.

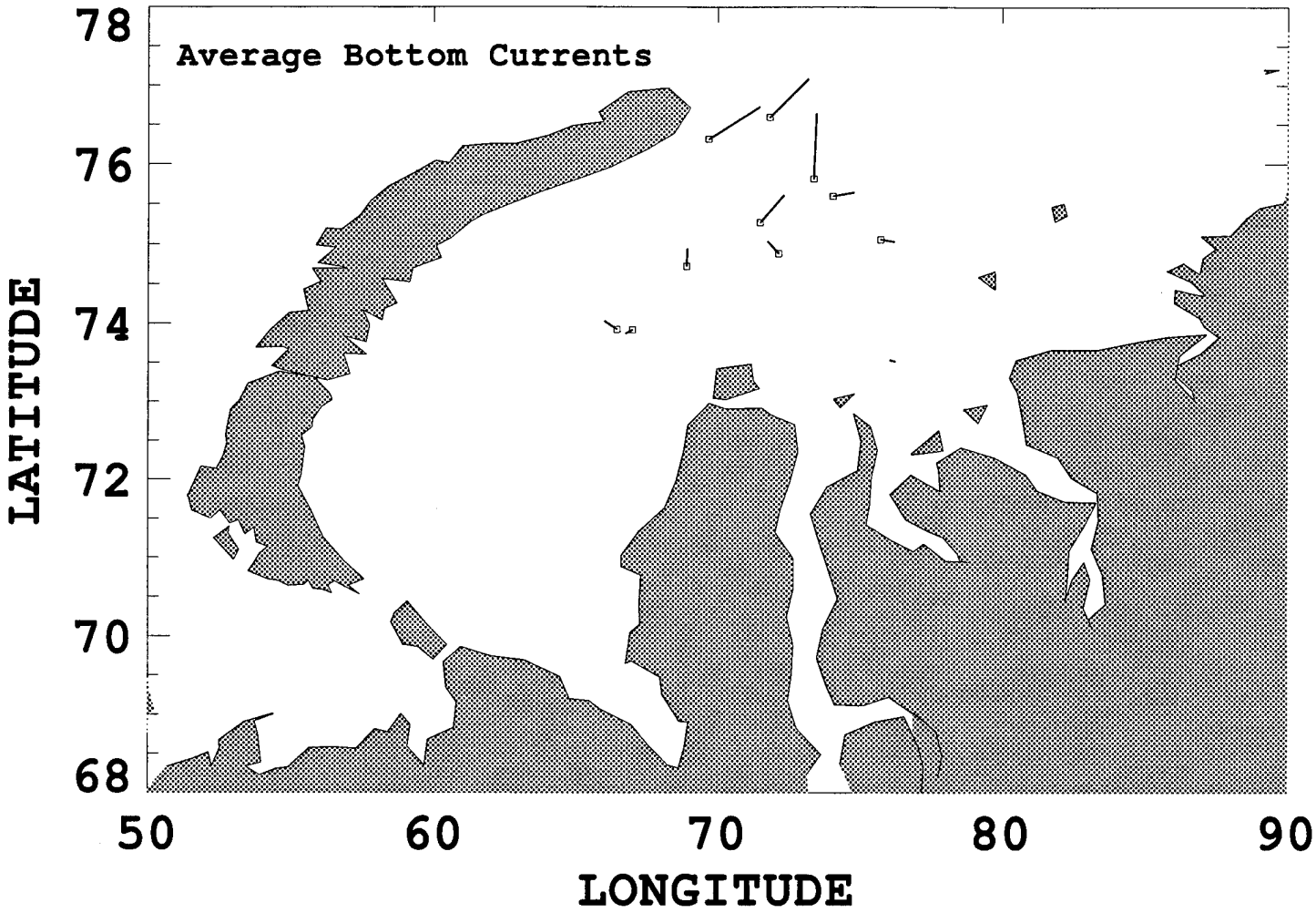


Figure 4.7 Average bottom current vectors. "Foot" of vector and location of mooring is given by the small dot. Flow is away from this dot. A vector length of 10 cm/sec current is equal to one degree of latitude. Oven the delta and delta edge, the current sensors were at 3 m above the bottom. In the Trough area, the sensors were at 10 m above the bottom.

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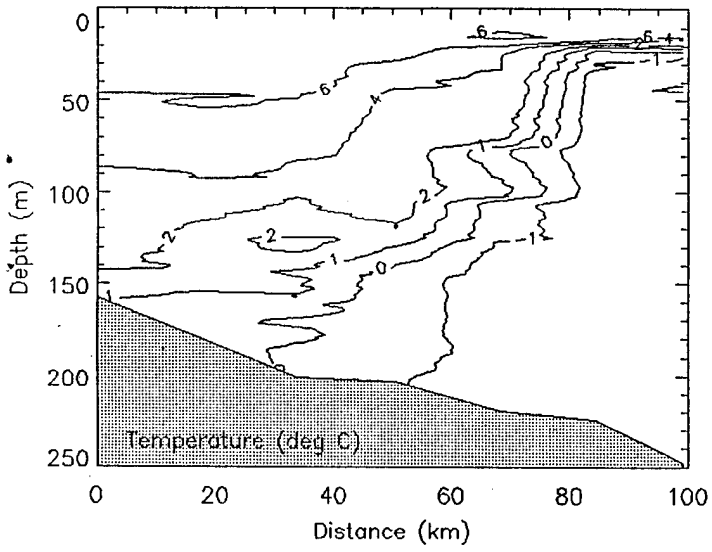
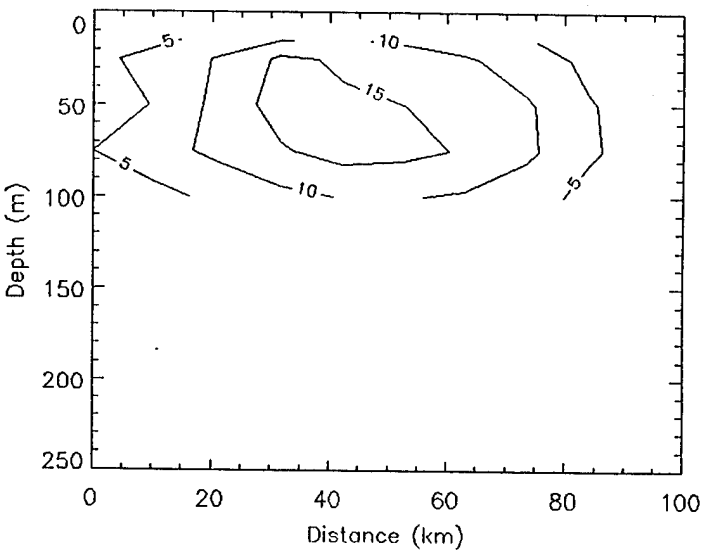
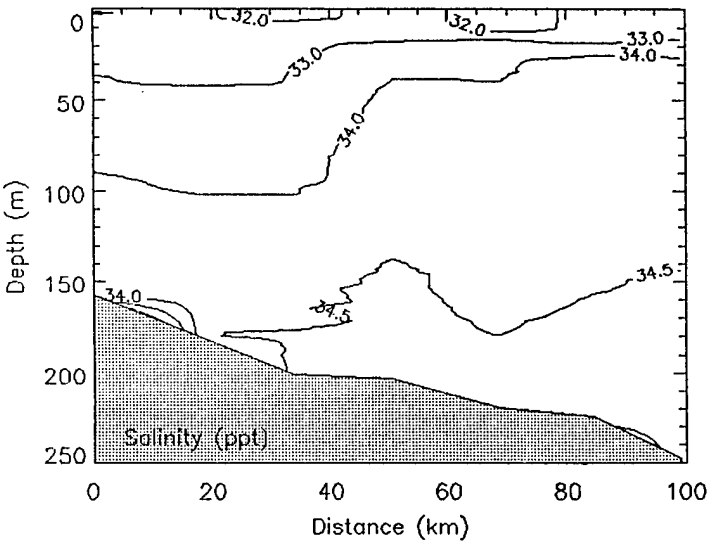
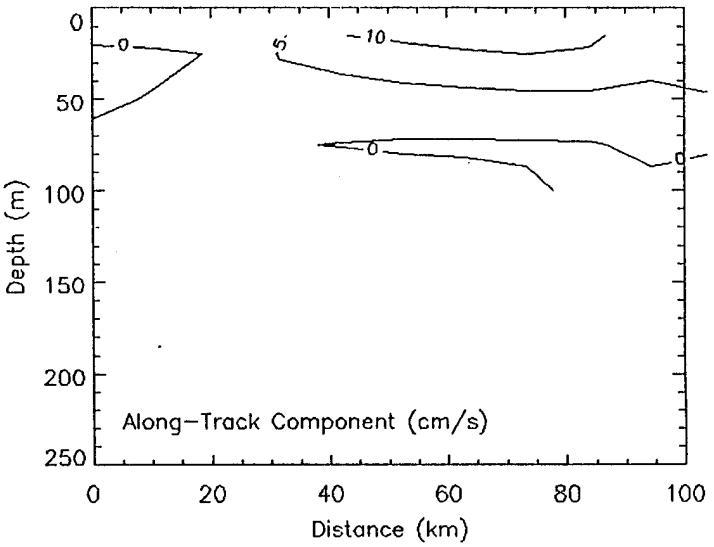
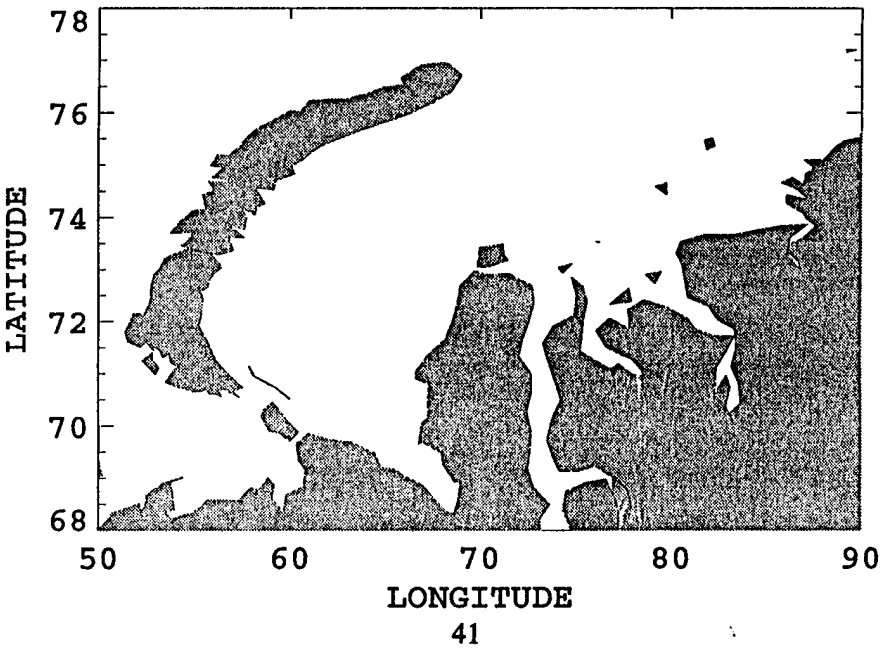
Figure 4.8 (opposite page) ADCP and CTD section across the Kara Gate (location of section given in the map at the bottom of the figure). Temperature (degrees centigrade) and salinity (parts per thousand) versus depth along the section are presented at the left of the figure and flow perpendicular (upper) and along (lower) the section are presented along the right of the figure. Speeds are given in cm/s with positive components into the Kara Sea and northwestward along the section.


Depth (m)
Distance (km)
Temperature (deg C)


Depth (m)
Distance (km)


Depth (m)
Distance (km)
Salinity (ppt)


Depth (m)
Distance (km)
Along-Track Component (cm/s)


LATITUDE
LONGITUDE

5.0 PRELIMINARY CONCLUSIONS

In summary, we met or exceeded most of the technical goals of oceanography and sample collection during the expedition. In particular the number of stations for sample collection exceeded our best case scenario. This was due in part to the very favorable weather conditions during most of the cruise, an extra day spend in the Kara Sea due to a short crossing of the Barents Sea and the cooperative efforts of the technical staff and crew.

A goal of the EPOCA 95 cruise to increase international cooperation in this research was met through our participation and the participation of a scientist from the International Atomic Energy Agency Marine Environment Laboratory (IAEA-MEL). It is hoped that Russian Navy scientists could participate in the planned EPOCA-96 cruise.

5.1 Survey of Radioactivity and Radiochemistry

The preliminary screening of the sediments and Cs adsorption filters from water samples show little or no activity above the prevailing values in the region. The only anthropogenic γ-ray emitting isotope observed in the measurements is ^{137}Cs. The preliminary analysis indicates that the activity is equal or lower than previously reported on other cruises. No levels have been observed that constitute an immediate or near term radiological risk.

The ^{137}Cs values in the water samples appear to be lower than the 1992-1993 Norwegian-Russian cruise data. The results do show a clear trend of higher activity levels in the deep samples compared to the surface samples. Much more information will be obtained through the laboratory analyses of the samples collected so it is premature to draw any definitive conclusions from the at-sea results.

We successfully demonstrated the ability to handle the at-sea K_d experimental protocol safely without any measurable contamination in one of the most rigorous sea environments. Interesting differences between the filters and controls were observed even at low sediment concentrations. The scope of this data set should also yield great benefit for risk assessment in the Kara Sea.

At all the stations surveyed, the levels of activity in samples brought on board ship were within the normal range expected. At no time were any personnel exposed to any radioactivity above normal environmental levels as a result of any sampling operations. A limited exposure from the tracer solutions is expected for the personnel involved in their handling but no contamination of working or storage areas was observed.

5.2 Oceanography

In general, the Kara Sea surface water was both warmer and more saline than in previous years. It is expected that this was due to lower river outflow and an extended summer.

Many of the circulation features that were previously noted were confirmed in the 1995 EPOCA cruise. Flow from the rivers went both westward and northwestward. However, we did not find flow toward the east, at least not in the near vicinity of the river mouths. In contrast to published atlases, we found that the surface circulation was principally northward in the western half of the Kara Sea, including a relatively strong input through the Kara Gate of water with characteristics of Pechora Sea Water. Some excellent sections across the Kara Gate and across the northern tip of Novaya Zemlya should enable us to improve our knowledge of input/output conditions for models. The relatively thin cap of warm water (6 deg C and 15 m thick) laid over a deeper pool of -1.8 deg C water is characteristic of the Kara Sea. This water was cooler than surrounding bottom water in the higher Arctic and may be indicative of limited circulation below the surface cap.

During EPOCA 95, we concentrated moorings along the northwestern delta edge. Our aim was to test a concept regarding limited spreading toward the west due to a delta edge current. Preliminary indications are that the limiting effect is not substantial.

Appendix 1 Radiation Safety Plan for Environmental Stations

RADIATION SAFETY PLAN FOR THE EPOCA-95 CRUISE

Radiation sources that may exist in the Kara Sea are all in the form of objects on the sea floor. Radioactivity may have leaked into the seawater, but clearly the largest health threat is posed by the potentially radioactive objects themselves. The possibility of coring through a radioactive object is the largest source of concern as far as safety goes. It is possible, however, that sea water or sediment in the vicinity of a highly radioactive (and leaky) object may itself contain unsafe levels of radioactivity. Therefore all samples must be checked for hazardous levels of radioactivity **before** they are brought onboard.

The procedure for bringing a sample onboard will be as follows.

1. When a sample is first being brought up, only those personnel necessary to the operation will be present. They will be wearing film badges.

2. Sample will be surveyed with a gamma meter on a long pole while it is still suspended over the side.

3. Any sample that shows gamma radiation in excess of 25 mRem/hr will be immediately dropped back into the water. After it has been dropped and the sampler brought back up, the sampler must be hosed off and checked before it is brought onboard. If an acceptable level of radioactivity cannot be achieved, then that particular sampler will most likely have to be abandoned.

4. Samples showing gamma levels from 5-50 mRem/hr will be left suspended while a gamma spectrum is collected, then they will be dropped into the water.

5. Samples showing gamma levels from .5-5 mRem/hr will be brought onboard, but left on the crane while a close-in gamma spectrum is taken. Then they will be lifted up, and dumped back into the water.

6. Samples showing levels above background, but less than .5 mRem, will be brought onboard. A swipe will be taken and counted for charged particle radiation. A gamma spectrum will be taken while the charged particle counting is going on. If they show a charged particle hazard, then they will be dropped back over the side. If the charged particle hazard is no greater than the gamma, then the samples can be removed from the cranes and prepared for storage. The stored samples will be wrapped in plastic (so they won't contaminate anything else), clearly marked, and then stored. Personnel handling these types of samples must be wearing plastic gloves, which are disposed of before the next

sample is taken. The disposal container will be one that is separated from all other types of waste.

7. Samples that show no gamma activity over background will be immediately onboard. A swipe will be taken and counted. While the counting proceeds, sub-samples will be taken. Given the nature of what we are looking for, it is exceedingly unlikely that a sample showing no gamma activity will contain a hazardous level of charged particle radiation. Reactor waste, for example, contains many different isotopes. Some of these have charged particle radiations without significant gammas. The probability of finding these in hazardous levels in the absence of the many other gamma emitting isotopes is very, very small. It is not, however, completely impossible. Therefore nobody should be forced to participate in the sub-sampling process until after the counting has been finished. It is also marginally possible that some small charged particle activity might be found on a sample showing no gamma activity. If this turns out to be the case, then the samples will be treated and stored like those in point 6 above.

Radiation safety on the cruise will be the responsibility of Steve King and an alternate to be designated. One of these people must be present whenever a sample is brought onboard. The radiation safety measurements and decisions outlined in 1 through 7 above will be made by them. The maximum cruise dose allowed to anyone onboard will be 40 mRem.

All US personnel participating in the cruise will have to have their radiation exposure histories forwarded to NRL well in advance of the cruise. Film badges will be provided by NRL, and must be worn during the cruise whenever a person is working with a sample, or a sampling operation. Film badges will also be offered to any foreign nationals on the cruise who wish them. Also, all foreign nationals will be informed of the radiation safety precautions that US personnel will be following, but it is up to them to decided whether or not they wish to follow them.

All radiation detection and health safety equipment will be provided by NRL. If any low level wastes are generated they will be stored in one place. There will be no high level wastes, because nothing that is significantly radioactive will be brought onboard.

The ship has a small clinic onboard but no doctor. The captain has had some medical training. In the extremely unlikely event of a radiation injury, the injured person would have to be returned to port for treatment. If a person is cut by a contaminated object, the cut will be thoroughly cleaned and then checked for radioactivity by survey meter and swipe.

All US personnel are responsible for being familiar with the procedures outlined in this document, and for memorizing the accompanying guidelines. All US personnel must attend

onboard training in basic radiation safety and dress-out procedures. This training will be given by Steve King.

Radiation Safety Procedures for Trilateral Military Research Expedition to the Kara Sea
25 August to 3 October 1995
Research Vessel: H.S. Sverdrup

PURPOSE OF INVESTIGATION

Amidst a background of reasonably well-documented sources of anthropogenically-derived radioactive contamination in the Arctic marine environment (nuclear weapons testing, releases from nuclear installations including European reprocessing plants and the Chernobyl accident), a new source has been recently identified. In 1992, Russian authorities revealed that, beginning in the mid-sixties, substantial quantities of nuclear wastes were discharged by the former Soviet Union into several shallow Arctic seas. These activities have generated concern over the potential long-term threat of contaminant releases from the dump-sites and/or former Soviet Union military installations.

As part of the International Atomic Energy Agency's (IAEA) responsibilities to the London Convention 1972, the IAEA enlisted the involvement of experts from relevant Member-States in a program to address concerns over possible human health and environmental impacts of radioactive contaminants in the Arctic. Dr. Carroll was selected by the U.S. government to contribute expertise in the field of marine radiogeochemistry.

The expert's primary mission is to identify and investigate key environmental variables of the shallow Arctic marine ecosystem that control the mobility of contaminants via transport by sediments and seawater. The determination of radionuclide transport mechanisms is a critical first step in estimating the risks to human health and the environment posed by contamination in Arctic Seas.

The objective of the field program conducted by Dr. Carroll as part of the Trilateral Military Research Expedition is to measure on-site distribution coefficients for key radionuclides of interest. A distribution coefficient (K_d) is the concentration of radionuclide per unit dry mass of sediment divided by the concentration of radionuclide per unit volume of seawater. Low K_d's are measured for radionuclides that are found primarily in seawater (e.g. ^{137}Cs) while high K_d's are measured for radionuclides that rapidly sorb onto sediment (e.g. ^{241}Am). Factors controlling these values are still poorly understood. This is especially true for the Russian Arctic, where data are sparse because access has been limited until recently.

ACRONYMS

MEL- the Marine Environment Laboratory of the International Atomic Energy Agency
RSO- Radiation Safety Officer
HDPE- High Density Polyethylene (bottles)
NRPA- Norwegian Radiation Protection Authority
ml-milliliter
PWB - Plexiglas work box
RWZ - radiation work zone

STORAGE OF RADIOISOTOPE STOCK SOLUTIONS

All radioactive stock solutions will be maintained by the radiation safety officer (RSO). Dr. Steven E. King[1] (Research Physicist, Radiation Detection Section, U.S. Naval Research Laboratory, Washington, D.C., U.S.A.; Phone (202)767-5463) will act as the RSO for this expedition (see attached abbreviated vitae). Each radioactive stock solution will be in a 20 ml HDPE bottle sealed with parafilm. As an added precaution, each bottle will be placed inside a capped vial (volume = 50 ml). The vials will be stored in individual lead containers provided by the NRPA[2]. The containers will remain locked in a storage box for release only by authorization of the RSO.

RADIOACTIVE ISOTOPES IN STOCK SOLUTIONS

Two 20 ml HDPE bottles each with 0.4 MBq ^{137}Cs
Two 20 ml HDPE bottles each with 0.2 MBq ^{57}Co (inorganic)
Two 20 ml HDPE bottles each with 0.4 MBq ^{241}Am
(volume in each vial is 2 ml)

LABORATORY SET-UP

A radiation work zone (RWZ) will be established and clearly marked using standard radioactivity tape. A grid pattern will be established in the RWZ so that if contamination occurs, the sub-area of contamination can be easily distinguished. The RWZ will be located in a low traffic area of the laboratory designated by the RSO. No untrained personnel or personnel not assisting in the procedures will be permitted to enter the designated RWZ. All work with radioactivity will be conducted in a Plexiglas box (PWB) that has been designed specifically for this program. The box will be securely fastened to a countertop within the RWZ. The box will have a 10 cm high x 5 cm wide Plexiglas barrier in front in which lead bricks will be placed (see attached figure). The box will be lined with benchcoat and disposable polyethylene sheeting. The sheeting will be changed daily. Two plastic tubs with lids will be secured inside the box, one for contaminated items and one for uncontaminated items. The tubs will be lined with aluminum foil and absorbent paper. A small waste bin lined with a plastic bag will be placed inside the box for disposal of pipette tips and absorbant papers. A liquid waste bottle will be fastened to the side of one wall. A squeeze bottle containing 4N hydrochloric acid will be fastened to the wall for rinsing all non-disposable materials used in the procedures. A squeeze bottle containing de-ionized water and a squeeze bottle containing liquid soap will be fastened to the wall for general usage as well. A floor mat and polyethylene sheeting will be placed on the floor directly in front of the PWB. The sheeting will be changed after usage of the area. The floor mat will be discarded at the end of the expedition.

[1] Dr. King has previously participated in expeditions on the H.S. Sverdrup.
[2] The lead containers have already been secured by Dr. Marit Krosshavn of the Norwegian Defence Research Establishment.

GENERAL SAFETY PRACTICES

1) Detailed records of all experimental work, accidents and radiation monitoring will be maintained throughout the expedition.[3]
2) A radiation safety inspection of the ship will be conducted before any radioactive materials are brought on board the ship. Background radiation levels will be measured using swipe samples collected from different locations onboard the ship. A survey of fixed gamma/beta activity using a GM counter will be conducted as well.
3) The use of radioactive materials will be stopped at anytime by request of the RSO, the chief scientist or the captain of the ship.
4) Each day in which radioactive samples are to be handled, the experimenter will confer with the RSO to verify that such work is deemed safe.
5) A dosimeter badge will be worn at all times when within the perimeter of the radiation work zone.
6) No work will be performed in rough seas.
7) No work will be performed when there are no assistants in the laboratory authorized to enter the radiation work zone and to help in an emergency.
8) All materials used in the handling of radioactivity will be labeled with radioactivity tape.
9) All work will be conducted wearing a lab coat which will be discarded at the end of each day. Before discarding the lab coat will be surveyed. If any activity is detected a check will be made for skin contamination.
10) All work will be performed wearing double-layered disposable gloves that will be changed often.
11) All materials used in the PWB (e.g. polyethylene sheeting, aluminum foil, sorbing towels, pipettes, gloves, lab coat) will be removed at the end of each day.
12) The RSO will be present during the use of stock solutions.
13) A large radioactive waste bin and a large bidon for liquid waste will be used to collect and store disposed items at the end of each day and securely stored to withstand rough weather at sea.

SAMPLE COLLECTION AND PREPARATION

Surface water, bottom water and bottom sediments will be collected at 20 stations in the Kara Sea. For each station, a 200 ml subsample of surface water, a 200 ml bottom water subsample and three 200 ml subsamples of filtered bottom water will be placed in 250 ml HDPE bottles. A small amount of bottom sediment (approximately 500 mg) will be added to one of the bottles of filtered seawater to make a sediment slurry. A small subsample of the slurry (approximately 4 ml) will be added to another bottle of filtered seawater. The bottle containing the concentrated sediment slurry will be stored for return to the MEL. The remaining 4 bottles will be stored in trays in a refrigerator purchased specifically for this work. The same procedure will be conducted at the next sample collection station in the Kara Sea.

[3]A record of these activities will be sent to the NRPA upon the vessel's return to Norway. A summary report of the expedition will be provided to the NRPA no later than one month after the completion of the expedition.

RADIOACTIVE TRACER WORK

The eight samples will be removed from the refrigerator and placed in the Plexiglas box next to a tub designated for contaminated materials. The bottles will be transferred from the carrier outside of the tub to one that is placed inside the tub. Radionuclide tracer solutions will then be added to each of the eight samples (4 from each station) using the following protocol[4]. With the assistance of the RSO, one of the two sealed bottles of ^{134}Cs stock solution will be handed to the researcher to be transferred to the tub. 10 kBq of the stock solution will be added to each sample bottle using a digital pipette. The stock solution will be sealed and returned to the storage area. Again with the assistance of the RSO, one of the two sealed bottles of ^{57}Co stock solution will be transferred to the tub. 5kBq of the stock solution will be added to each sample bottle using a digital pipette. The stock solution will be sealed and returned to the storage area. With the assistance of the RSO, one of the two sealed bottles of ^{241}Am stock solution will be transferred to the tub. 10kBq of the stock solution will be added to each sample bottle using a digital pipette. The stock solution will be sealed and returned to the storage area.

After the addition of a tracer to a sample bottle the bottle will immediately be sealed. The samples will be returned to the refrigerator for 5 days. After 5 days the samples will be removed from the refrigerator. Each sample will be passed through a filter to separate the sediment from the water. The filter will be placed in a petri dish and sealed with parafilm for return to the MEL. A 20 ml subsample of the filtrate (seawater) will be placed in a 30 ml HDPE bottle, sealed with parafilm, and placed in a capped plastic vial and stored for return to the MEL. The remaining 160 ml filtrate will be placed in a liquid waste bottle for disposal. As mentioned previously, at the end of each session in the PWB, all materials used in the work, e.g. pipette tips, gloves, surface protective material, and lab coat will be disposed of in a low-level radioactive storage bin. All non-disposable materials will be rinsed with 4N HCl and the effluent collected in a waste bottle for proper disposal. When not in use, all items in the PWB will be stored in plastic tubs with lids that are securely fastened to one of the walls of the box. All samples to be returned to the MEL will be stored in one of 4 large coolers segregated to maintain all bottles and petri dishes in an upright position at all times. The coolers will be tightly secured for storage in a remote section of the outside deck of the ship.

ROUTINE RADIATION MONITORING

Radiation monitoring will be conducted within the RWZ each day that radioactivity is handled. A GM counter will be used to conduct sweeps in the area to detect any surface contamination. If detected, surface wipes will be conducted and measured on the on-board NaI detector which can distinguish among the three radionuclides being used on-board the ship. Fixed activity will be monitored with portable alpha and beta/gamma meters. Each week, a more extensive survey will be conducted of the laboratory beyond the confines of the RWZ to ensure that no radioactivity has been transported to other areas of the laboratory. Additional surveys will be conducted near the locked storage box containing the stock solutions.

[4]No more than one stock solution containing 0.4 MBq will be handled at any time.

Acceptable Surface Contamination Levels	
Beta/Gamma Emitters	Average: 83 Bq/ 100 cm^2 Maximum: 250 Bq/ 100 cm^2 Removable: 16.66 Bq/ 100 cm^2
Transuranic (^{241}Am)	Average: 1.667 Bq/ 100 cm^2 Maximum: 5 Bq/ 100 cm^2 Removable: 0.3 Bq/ 100 cm^2

EMERGENCY PROCEDURES

Any spills will result in the immediate notification of the RSO. Steps will be immediately taken to contain the spill to as small an area as possible. Because all work will be performed in tubs in an enclosed box, the spill will be retained within a well-defined region. Absorbant towels will be used to confine the spill further. The area of the spill will be rinsed with soap and water to remove the radioactivity and sorbed onto absorbant towels. All materials used to clean up the spill will be disposed of in a sealed plastic bag and transferred to the radiation waste bin. If subsequent gamma surveys show radioactive contamination exists, the area will be re-cleaned and tested again. If additional surveys show radioactive contamination exists the tub will be disposed of and a new tub will be used for all subsequent work. No work with radioactivity will continue without the re-authorization of the RSO.

POST-CRUISE CLEAN-UP AND INSPECTION PROCEDURES

At the completion of the experimental work, all items used during the handling of radioactivity will be disposed of in the radiation waste bin. The area will be thoroughly cleaned with soap and water and the cleaning fluid will be disposed of in the liquid waste bidon. Once the expedition returns to Hammerfest, the PWB will be cleaned thoroughly and dismantled. The RWZ will be cleaned again. An extensive survey of the RWZ and other areas of the vessel will be conducted. For any areas where radiation exists that is above acceptable levels additional decontamination work will be conducted. All samples collected during the expedition will be packaged for transport to Oslo where they will be transferred to an authorized shipper of radioactive materials[5] for transport to the MEL. All radioactive waste will be disposed of as directed by the NRPA.

[5] The shipping agent, *Dangerous Goods* in Oslo is being secured to handle the transport of samples from Oslo to Monaco.